HYGIENE

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PREFACE

One of the most remarkable features in the educational movement of the present day has been the increased effort to diffuse a knowledge of the relations which exist between our health and the air we breathe, the water and food we consume, the soil we tread and the buildings we occupy. Known under the various current names of Sanitary Science, Public Health or Hygiene, this subject involves an acquaintance with such diverse sciences as physics, chemistry, geology, engineering, architecture, meteorology, epidemiology, bacteriology and statistics. To these, strictly speaking, may be added the study of the law or those legal enactments which concern the sanitary well-being of communities.

When, therefore, the publishers asked us to prepare a small work on this many-sided subject, to form one of their Science Manuals, such as would present its facts and principles fully, briefly, and yet in simple language suitable for both non-professional and professional readers, we were early confronted with the difficulty of deciding what to include and what to omit.

We have endeavoured to consider the general laws of health, the causes of disease and the means of combating them, in the simplest language, and, by divesting them, where possible, of scientific technicalities, to make clear, even to non-scientific readers, those great natural laws and processes upon which our healthy life so much depends. While doing so, we have felt bound to be not unmindful of the wants of others, desirous of entering more fully into the study of what should be a great and practical subject in our national education. The work is not to be regarded as a substitute for the regular and more advanced books which discuss the subject of hygiene in its many bearings,

but rather is intended as an introductory manual for the use of junior students or others, preparatory to a more extended and practical study of public health work.

As regards chemical analysis, we have only attempted to give such details as appeared absolutely necessary in order to make the book useful to those capable of appreciating the meaning and value of results. For their practical application, laboratory experience and instruction are essential. In order to encourage uniformity of international knowledge, the metric system of weights and measures is used.

In view of the increasing public interest taken in facts and laws concerning Weather, Climates, and Vital Statistics, short chapters have been given upon these subjects, in non-technical language as far as possible.

For illustrating some part of the text, we are indebted to Mr. L. Casella for the use of drawings of various meteorological instruments, and to Mrs. Bruce for several original diagrams. In order to further illustrate the text, use has been made of four diagrams published by the Local Government Board in their annual reports.

WEST CLIFF, WOOLSTONE, SOUTHAMPTON,
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CHAPTER I.

AIR.

We are all familiar with the fact that the earth is surrounded on all sides with a gaseous envelope, the atmosphere (from the two Greek words, ἀτμὸς, smoke, and σφαῖρα, a globe), or, as it is more commonly called, the air.

This air, when pure, is free from colour, taste, or smell, and is really a mechanical mixture of gases, possessing the properties of weight, expansion, and diffusibility. That the air we breathe is not a chemical compound, but only a mechanical mixture, is known by the facts that the gases of which the air is made up do not exist in it in their proper combining proportions, and that the relative amounts of these gases in the air cannot be expressed by any chemical formula. Moreover, on mixing the gases of which air is composed, together in the same proportions as they exist in air, there is no manifestation either of heat, electricity, or change of volume, such as would result were air a chemical combination.

The Composition and Physical Properties of Air.

The chemical composition of the dry atmosphere or air in 100 measures or volumes may be roughly taken as being 79 of nitrogen and 21 of oxygen with a small proportion of carbonic acid. If the calculation be made by weight, there would be in 100 parts of dry air, roughly 77 of nitrogen and 23 of oxygen. As an average of many examinations, the composition of pure air appears to be as follows :—

	By Volume.	By Weight.
Nitrogen	79·02	76·84
Oxygen	20·94	23·10
Carbonic acid	0·04	0·06
	100·00	100·00

Besides the above gases, the air always contains a certain quantity of watery vapour, together with various impurities.

Nitrogen is the main constituent of our atmosphere. It is a chemical element found everywhere in Nature, particularly in the tissues of all animals and plants, and is essential to the existence of all forms of life. In the air, nitrogen appears to act as a diluent of the oxygen, evidently reducing its strength and rapidity of action, much as water is used to dilute spirits or wine. It is probable that the nitrogen of the air may serve to supply plants with a certain amount of nourishment in the form of oxides of nitrogen, which are washed down out of the air into the soil after storms or rain, but on this point as yet very little is known.

Pure nitrogen is a colourless, tasteless, and inodorous gas: it is quite incombustible and incapable of supporting either combustion or life; it is from this latter peculiarity that foreign chemists call it *azote*, a word derived from the Greek, meaning "no life." We English people call it nitrogen, because it is the element which gives birth, so to speak, to nitre.

Nitrogen can be easily prepared from the air, by removing, by means of phosphorus, the oxygen with which it is mixed. A piece of common phosphorus is wiped dry and placed in a small porcelain capsule floating on some water contained in a dish. A light is applied to the phosphorus and the dish quickly covered with a glass bell jar. The phosphorus having a great liking for oxygen will burn until the last trace of that gas is removed from the air under the bell jar, forming as it burns white fumes of phosphorus pentoxide. These gradually become dissolved in the water, forming in it meta-phosphoric acid, while the water itself slowly rises in the dish to occupy the space originally taken up by the air, leaving the empty space above the water filled by a colourless gas which is almost pure nitrogen.

Nitrogen may also be isolated from the atmosphere by passing air slowly over red-hot copper, which absorbs the oxygen and leaves the nitrogen.

Oxygen.—Although nitrogen practically constitutes four-fifths of the atmosphere, the most important constituent of the air is oxygen. This gas, which when pure is clear and colourless, is necessary for all forms of life; all animals, if deprived of it, dying at once. It is also needed for every kind of combustion such as the burning of wood or coal, and is necessary for every kind of light except the electric light. Oxygen exists in the air in a free state, and is not chemically combined with the nitrogen of the atmosphere, but only mixed with it.

Oxygen can be abstracted and recovered from the air by heating various metallic oxides and peroxides. For example, red lead, heated, gives off oxygen and leaves litharge or plumbic oxide: thus $2Pb_3O_4 = 6PbO + O_2$. Similarly, by the alternate conversion

of a substance called baric oxide into a still higher oxide or peroxide by heating it in air and afterwards decomposing it by further heat, back to the original compound, a continuous process for the production of oxygen is obtained: thus $2BaO_2 = 2BaO + O_2$. The reason of being able to do this is due to the fact that baric oxide contains 137 parts by weight of the metal barium, combined with 16 parts by weight of oxygen, and if heated in purified air absorbs 16 parts more of oxygen forming the baric peroxide. If the temperature be still further raised, the extra 16 parts of oxygen are given off, and the baric peroxide returns once more to baric oxide, and can be further utilized again for the absorption of more oxygen from the air.

A modification of oxygen occurs in small traces in the atmosphere, and is known by the name *ozone*. This is a gas of probably great importance and is a kind of intensely strong oxygen. It is very plentiful in fresh pure air, and least so in places where there is much organic matter, or where men or animals are crowded together. Ozone is a powerful oxidizing agent, and is produced whenever an electrical discharge takes place in air due to the conversion of some of the atmospheric oxygen into the extremely active modification, ozone, which however can be reconverted into ordinary oxygen by the action of heat. Ozone may be readily recognized by its odour, which is so pungent that one volume present in $2\frac{1}{2}$ million volumes of air is said to be easily detected by the sense of smell. It is pungently noticeable in country and sea air.

The most usual test for detecting traces of ozone in air is to expose strips of blotting paper moistened with a mixture of potassic iodide and starch, when if any ozone be present a blue tint is produced owing to the decomposition of the iodide and the formation of a potassium oxide and iodide of starch. This tint, however, is not very reliable, as there are often traces of other gases present in the air which give the same result. If such be suspected, in order to be quite sure that it is ozone only which has turned the paper blue, it is necessary to use a second test, which is to soak red litmus paper with a very dilute solution of the iodide of potassium. The potassium oxide produced, causes an alkaline reaction, and turns the red paper to blue. Although small traces of ozone constitute a powerful agent for the purification of the air from waste organic matter, in larger quantities it acts as a violent irritant to the eyes and nose.

Carbonic Acid.—Samples of air, no matter where collected, always contain another gas besides nitrogen and oxygen, called carbonic acid, and this usually to the extent of about 4 volumes in 10,000 of air. Carbonic acid is a clear colourless gas containing

12 parts by weight of carbon combined with 32 by weight of oxygen. It is produced when carbon, which forms the greater part of coal, is burnt. The carbon unites with oxygen, their union producing both light and heat with the giving off of carbonic acid gas. For this reason, it is the invariable product of the burning of animal and vegetable matter in the air, and is the choke-damp which collects in mines after an explosion. It is also largely given off by men and animals, as well as from the earth, more particularly in volcanic districts. Under the influence of sunlight, plants breathe in carbonic acid, retaining the carbon and setting free the oxygen. In the dark, this action of plant life is reversed, the oxygen being absorbed and carbonic acid given off. Carbonic acid, or as it is sometimes called, carbon dioxide, exists largely in Nature in combination, forming compounds called carbonates. It is readily obtained by adding dilute hydrochloric acid to a form of calcic carbonate such as marble or limestone contained in a flask and so arranged that the escaping gas can be collected into a suitable vessel. The acid acts upon the calcic carbonate, forming calcic chloride, water and carbonic dioxide; this latter escapes as a gas while the two former remain behind.

Carbonic acid is faintly acid in taste and smell, and behaves in an exactly opposite manner to oxygen, inasmuch as it can neither support life nor combustion. It is a very heavy gas, being just 22 times heavier than hydrogen, which is the lightest of all gases. It is soluble in water, but the volume so dissolved depends largely upon temperature and pressure. The amount of carbonic acid present in the air varies according to place and season. Angus Smith found 0·36 parts per 1000 of air in London streets; 0·4 in Manchester, while in country districts and on the tops of hills or mountains about 0·3 parts per 1000 of air has been the average amount found in the atmosphere. In inhabited rooms and stables, of course much larger quantities have been found. To the extent of 0·4 parts in 1000 of air carbonic acid is a normal constituent of our atmosphere, and unless it exceed that quantity it cannot be considered an impurity.

Watery vapour is always present in air. The presence of this in the atmosphere is due to the fact that water evaporates at all temperatures, so that a slow but invisible escape of water vapour is taking place from the earth's surface at all times into the air space which encircles the globe. If we leave a dish full of water exposed to the air, it sooner or later dries up, because the water goes away slowly in the form of vapour. This phenomenon is sometimes spoken of as the tension or elastic force of aqueous vapour, and is such that it can be measured or stated

to exercise pressure equal to so many inches of mercury. The amount of watery vapour which the air can take up varies with the heat of the air, the greater the temperature the greater the amount of water vapour which can be taken up. This explains why water dries up much quicker in warm weather than in cold. The following table shows roughly the weight of watery vapour which a cubic foot of air can hold at different temperatures:—

At 30° F.	2 grains.	At 74° F.	9 grains.
,, 41° ,,	3 ,,	,, 77° ,,	10 ,,
,, 49° ,,	4 ,,	,, 80° ,,	11 ,,
,, 56° ,,	5 ,,	,, 83° ,,	12 ,,
,, 61° ,,	6 ,,	,, 86° ,,	13 ,,
,, 66° ,,	7 ,,	,, 88° ,,	14 ,,
,, 70° ,,	8 ,,		

Or, in another way, it can be said that a quantity of completely moist air at 32° F. holds in suspension an amount of vapour equal to $\frac{1}{160}$th part of its own weight; at 59° F. $\frac{1}{80}$th; at 86° F. $\frac{1}{40}$th; at 113° F. $\frac{1}{20}$th; and at 140° F. $\frac{1}{10}$th. Expressed mathematically, it can be said that while the temperature advances in arithmetical progression, the power of the air to retain vapour increases with the rapidity of a geometrical series having a ratio of two. When air contains the full amount of watery vapour for the given temperature it is said to be saturated: and in proportion as it is more or less removed from the point of saturation and not in proportion to the precise amount of water it contains is air said to be dry or moist. Thus if air can hold 100 parts of moisture, but actually only holds 75 parts, it is said to be only three quarters moist, or to have 75 per cent. of humidity. The amount of moisture in the air can be determined by causing a current of air to flow slowly through tubes containing hygroscopic substances such as caustic potash or hydrochloric acid, which have the power of taking up or absorbing water, and then by weighing to note the increase in weight which has taken place, and knowing the exact volume of air which has been passed through, calculating the moisture present as a percentage. It is, however, more usual to determine the atmospheric moisture by means of instruments called "hygrometers," particulars of which are described in a subsequent chapter upon climate and weather.

While the amount of watery vapour in the air has a considerable effect upon the temperature of a place, its presence is absolutely necessary for life. A perfectly dry air not only would be unbearable, but would quickly prove fatal to both plants and animals. As a rule, the atmosphere contains from 1 to 1½ per cent. of water in a state of vapour, or from 50 to 75 per cent. of

the amount required for complete saturation. If the quantity be much above or below these limits, the air is either unpleasantly moist or dry.

The air being really nothing more than a mixture of gases, behaves exactly as and has the properties of a gas: that is to say, it has weight, expansibility, and diffusibility. Like any solid or liquid, the air has **weight.** That this is the case is shown by the fact that if a glass globe of known capacity be taken, exhausted of all air by means of an air-pump and then weighed, its weight then will be less than it would be if air were allowed to enter it. If the capacity of the globe be known, the difference between the two weights is the weight of that volume of air. By a modification of this method, and the exercise of certain precautions, the weight, not only of air, but of other gases, has been accurately determined. From experiments of this kind, it has been found that air is 773 times lighter than water, and that 100 cubic inches of dry air, when the thermometer is at 60° F., and the barometer is at 30 inches, weigh 31 grains; under the same conditions, the same volume of carbonic acid gas weighs $47\frac{1}{4}$ grains; while 100 cubic inches of hydrogen, which is the lightest known gas, weigh only $2\frac{1}{7}$ grains.

Since the air, therefore, has weight, it gives rise to *pressure* according to the same laws as those by which the weights of liquids produce pressure. If we imagine an upright cylinder, some miles in height, full of air and resting upon the ground with its top closed, and consider the air contained in the bottom ten feet of the cylinder, we can readily realize that this lower portion of air must support the weight of all the air above it, and transmit that weight to the ground beneath it, and also to the curved sides of the cylinder which contain it and that in a direction at right angles to the surface. Thus the pressure of the air in this imaginary cylinder increases from the top of the column to its base, and is equal to the weight of that column.

If we regard the atmosphere as a kind of fluid sea, some 40 miles in depth, surrounding the earth on all sides, we can realize that it exercises the same pressure as if it were a liquid of very small density. This pressure will be at right angles to any surface, and will lessen as we ascend from, and increase as we descend to, the level of the earth. As it has already been stated that the weight of 100 cubic inches of air is no less than 31 grains, it will be easily understood that the whole earth's atmosphere, which has been estimated to be not less than 40 miles in height, really exercises a very great pressure upon the earth's surface. The exact amount of this atmospheric pressure was first determined by an experiment made in 1643 by Torricelli, a pupil

of Galileo, which may be explained as follows :—A glass tube, closed at one end, is taken, having an internal diameter of $\frac{1}{4}$ inch, and being a yard long. After filling it quite full of mercury, and then stopping up its open end firmly with the finger, turn it upside down, and insert its open end into a vessel containing mercury. As soon as the finger is removed, the mercury will be seen to fall slowly in the tube, until, if the observation be made in the south of England, it stands about 30 inches higher than the surface of the mercury in the vessel. This vertical column of mercury will remain at 30 inches, in height, because it is prevented from falling any lower in the tube by the counterbalancing weight or pressure, as it is called, of the air. If this same experiment be performed on the top of a mountain or high land, the length or height of the mercurial column supported by the air will be less than 30 inches, because at elevated places the height and consequently counterbalancing weight of the atmosphere is less than at places at a lower level.

By a law of hydrostatics, the heights of two columns of liquids in communication with each other are inversely as their densities; hence it follows that the pressure of the atmosphere is equal to the weight of a column of mercury, the height of which is 30 inches. If, however, the weight of the atmosphere diminishes, which it does do in elevated places, the height of the column which it can sustain must also diminish. In the foregoing experiment, the sectional area of the tube may be taken to be equal to one square inch, and since the height of the column of mercury is 30 inches, the mercurial column is really one of 30 cubic inches. As a cubic inch of mercury weighs $3433\frac{1}{2}$ grains, or as near as possible half a pound, the pressure of that column of mercury on each square inch of surface is equal to $14\frac{3}{4}$ pounds. On a square foot, this would give a pressure of nearly a ton; and as the average superficial area of an ordinary man is 16 square feet, the pressure supported by such a man amounts to nearly 16 tons. This at first sight seems an impossible burden, but the effect of this enormous force is equalized by the contrary and equal pressure of it in all directions upon the body surface, whereby we are rendered totally unconscious of its existence. The instruments used for measuring atmospheric pressure are called barometers; their varieties and special features are discussed in a subsequent chapter.

Though the total weight of the atmosphere must always be the same, still its density, and consequently the pressure which it exerts, will vary according to local conditions. The most prominent of these conditions are its heat and its degree of dryness. Like every other gas, air expands with heat, and

assuming no variation in pressure, this is (according to the law of Charles) at the rate of $\frac{1}{491}$ or 0·00203 of its volume for each degree Fahrenheit; or $\frac{1}{273}$ or 0·00367 for each degree Centigrade. For this reason, a given volume of air at 50° F. is lighter than the same volume at 40° F.; and a cubic foot of air at 0° C. would weigh just twice as much as a cubic foot of air at 273° C. Similarly, moist air is lighter than dry air. The reason of this is as follows:—Air is really a mixture of 4 volumes of nitrogen (atomic weight being 14), and 1 volume of oxygen (atomic weight being 16). Each volume of air, therefore, is represented by $\frac{4 \times 14 + 16}{5} = 14{\cdot}4$. Now, moist air is air, *plus* water, in a gaseous or vaporous state; but water itself is a compound of 2 volumes of hydrogen (atomic weight 1) and 1 volume of oxygen, and as a compound gas, occupying 2 volumes, is represented by $\frac{16 + 2}{2} = 9$. That is to say, a volume of dry air weighs 14·4 and one of water vapour only weighs 9. These variations in the weight of hot or cold, dry or moist air are indicated by corresponding fallings or risings of the barometer, and explain why in England the barometer rises during dry easterly winds and usually falls with the damp westerly winds.

The **expansibility** of air, which plays a very important part in the theory and practice of ventilation, as we shall see later on, is really dependent upon two conditions; namely, the pressure under which it is, as expressed by the barometer, and the temperature at the time being. For a due appreciation of this power of air to constantly change its volume, it is necessary to understand and apply the two physical laws of Boyle and Charles. The law of Boyle is, that "the temperature remaining the same, the volume of a given quantity of air or gas is inversely as the pressure which it bears." In other words, this means that if a cubic foot of air is measured at 29 inches of barometric pressure, to know what it would measure, were the pressure 30 inches, it must be multiplied by 29 and divided by 30. Or, that a quantity of air which exactly measured 1 cubic foot at 29 inches of barometric pressure would only measure 0·96 cubic foot had the pressure been 30 inches, because $1 \times \frac{29}{30} = 0{\cdot}96$ cubic foot.

The law of Charles, which has already been alluded to, is, that "assuming no change in pressure, any gas or air expands or contracts $\frac{1}{491}$ (·00203) of its volume for every degree it is above or below 32° F. in temperature." If the temperature be on the centigrade scale, the ratio of expansion or contraction is $\frac{1}{273}$ (·00367) for each degree above or below 0° C. In other words, this means that 491 volumes of air at 32° F. become 492

at 33°, 493 at 34°, and so on. That is, as 491 *plus* or *minus* the given temperature is to 491 *plus* or *minus* the required temperature, so is the given volume to the required volume. As an example, we can say 100 volumes at 30° F. will become 104·09 volumes at 50° F. : because as 491 − 2 (489) : 491 + 18 (509) : : 100 : x = 104·09 volumes.

In actual practice, it is usually needed to make these two calculations or corrections together. For instance, suppose in a room with the temperature at 40° F. and the barometer at 30 inches, the volume of air was 1000 cubic feet, what would be the volume of that same air were the temperature to be raised to 60° F. and the pressure fall to 29 inches? Using the two equations combined, as follows,—

$$\frac{30}{29} \times \frac{491 + 28}{491 + 8} \times 1000 = 1075 \text{ cubic feet,}$$

we get that, under these altered conditions of pressure and temperature, what before measured 1000 cubic feet now measures 1075 cubic feet, consequently the excess of 75 cubic feet would escape out of the room.

It is only by rightly comprehending the great property of the atmosphere to expand or contract according to the above mentioned laws, that we can fully appreciate the causation or production of those movements of the air over larger or smaller regions which we in everyday life call winds or draughts. They are due to the simple fact, as already explained, that when over some large tract of land the air is warmed by the sun, it expands and rises, while from adjoining regions colder and heavier masses of air rush in to take its place. Similar but smaller movements of air, due to varying degrees of heat, density, and pressure, are constantly going on in and about our houses. It is the same cause which makes the warm air over a fire go up the chimney to be replaced by fresh and colder air entering by windows, doors, and cracks. Whenever a room or house is inhabited by human beings or warmed by lights and fires, a constant expansion of air is going on with an escape of the excess volume by the chimneys and doors or windows. By this means the equilibrium between one part of a dwelling and another is constantly being disturbed, and the air rarely if ever allowed to be absolutely still even over the most limited area.

From what has already been said, it will be gathered that, while the atmosphere has several constituents, each of them has its own particular weight: that while the carbonic acid is heavier than the oxygen, this again is heavier than the nitrogen, while the water vapour is lighter still. If the same laws or rules held good

for gases as regulate fluids we should expect that these various constituents of the air would form themselves into layers with the heavy carbonic acid near the ground, next above it the oxygen, then the nitrogen, and, above all, the watery vapour. As a matter of fact such is not the case, because of the action of another great law of Nature, known as the law of the diffusion of gases, which is such that it causes all gases to mix one with the other, no matter how they differ in weight.

The **diffusibility** of a gas is well and easily shown by the following simple experiment: take a U-shaped tube some 18 inches long, fix it at one end by a cork to a porous cell such as is used in electric batteries, and then fill the tube nearly full with some water. Next make some hydrogen, and fill with it a bell jar. If this bell jar containing the hydrogen be quickly placed over the porous pot, the hydrogen gas so rapidly diffuses through the pores of the cell or pot into the tube that the water is at once driven down, and spurts out at the open end. So, again, if we take two globes, and, having filled the lower one with carbonic acid and the upper with hydrogen, connect them together by a tube, although the hydrogen was in the upper globe, yet, after a short time, half of it will have gone down into the lower globe and half of the carbonic acid will have ascended into the upper one. Now we know carbonic acid to be just 22 times as heavy as hydrogen, yet the power of diffusion is so great that it has overcome the enormous force of gravity.

The rate at which this intermingling of gases can occur is largely influenced by their weights (densities). So much so that, according to the law of Graham, who first explained the fact in 1832, it is enunciated that "the force of diffusion is inversely as the square roots of the densities of gases." Thus, if we take two vessels of equal size, the one containing oxygen and the other hydrogen, and separate them by means of a porous plug, we shall find diffusion take place, and this will be in the proportion of 4 parts of the hydrogen into the oxygen to every 1 part of the oxygen into the hydrogen. This exact ratio of diffusion is explained by the fact that the density of the hydrogen is 1 as compared with the 16 of oxygen, hence the force of the diffusion is inversely as the square root of these numbers—that is, it is inversely as 1 is to 4, or just four times as great in the one which has one-sixteenth the density of the other.

It is this faculty of diffusion, possessed by all gases, which is the chief cause by which the composition of the air is kept constant, and which causes the carbonic acid formed so freely in our large towns and cities by combustion and breathing to be rapidly removed from where it is formed to other parts, where the processes

of vegetation and sunlight can break it up into carbon for the food of plant life and oxygen for the use of men. It is this remarkable action of the green colouring matter of plants, called chlorophyll, upon carbonic dioxide, which is the great compensating agency at work for keeping down the tendency of carbon dioxide to increase, and whereby Nature gets rid of what practically is the chief impurity in the air, with the result that the carbonic acid in the atmosphere at the top of a mountain is in much the same proportion as in the air at its foot—namely, that it rarely reaches a proportion of more than 0·04 per cent., an amount which is quite harmless to human life. Supplementary to the power of gaseous diffusion, we have the action of winds, which scatter and diffuse over a large area many impurities of the air which would be very hurtful if confined to any limited space. In a similar but lesser sense, dew, rain, and snow may be regarded as helping in the constant purification and dispersion of atmospheric impurities.

The Impurities of the Air.

Although the examination of pure air indicates it only to consist of nitrogen, oxygen, a definite amount of carbonic acid, not exceeding 0·04 per cent., and some watery vapour, the majority of samples of ordinary air betray the presence in them of various impurities, notably traces of ammonia, nitric acid, nitrous acid, various compounds of carbon—chiefly carbonic dioxide, carbon monoxide and carburetted hydrogen,—with a greater or less amount of suspended matter, such as soot, dust, epithelial cells, vegetable fibres, wool and silk fibres, particles of sand, chalk, or iron and the minute forms of life. These impurities of air are mainly the results either of combustion, respiration, emanations from sewers, marshes, or graveyards, or else the contaminations given off by manufactures and trade processes.

Ammonia is a compound containing 14 parts by weight of nitrogen along with 3 parts by weight of hydrogen. It is a colourless gas, marked by an intensely pungent odour, and quite unable to support combustion. Although traces are usually present in most air samples, it rarely exists in the atmosphere in greater amount than 3 parts in ten million and is formed in the main from the decomposition of decaying nitrogenous matter. When present, ammonia is usually in combination with some acid, such as nitric or carbonic. Being readily soluble in water, ammonia is quickly washed out of the air by rain, and carried down into the soil, in which it affords a valuable food for plants. Chemically, ammonia represents the main part of what is called the organic matter in

the air, and if condensed in water yields the so-termed albuminoid ammonia.

Nitric and **Nitrous Acids** are probably derived by the air in small quantities from decaying nitrogenous matter, while, too, a certain amount is produced in the air by the direct combination of oxygen and nitrogen during electrical disturbances. These acids, like ammonia, are washed down by rains into the soil, and there serve in the fertilization of various forms of vegetation.

Carbonic Acid has already been shown to exist to a limited extent in pure air. This limit has usually been placed at 0·04 per cent., or 4 parts in 10,000 of air, but it is probable that this limit is too high, and that in the purest airs the natural amount of carbon dioxide does not exceed 0·3 per 1,000 volumes. Any carbonic acid present in air, therefore, over and above 0·04 per cent. must be regarded strictly as an atmospheric impurity. This gas we know to be largely given off into the air by men and animals during breathing, by all processes of combustion or putrefaction, and by certain kinds of soil; it is increased by fogs, but lessened by rain, winds, vegetation and ventilation. The amount in the air is consequently variable, as will be seen by the following table, showing the various quantities found in different places by various observers.

	Carbonic Acid per 100 of air.
National School-room in Leicester (Weaver)	0·241
Public Library reading-room ,,	0·206
Assize Court, Manchester (Smith)	0·196
Tailor's workshop, Glasgow ,,	0·217
Strand Theatre, London ,,	0·101
Chancery Court, London ,,	0·193
Bedroom at night (de Chaumont)	0·230
Gosport Barracks ,,	0·060
Aldershot Barracks ,,	0·049
Street in Manchester (Smith)	0·040
Mine in Cornwall ,,	0·785
Chatham Convict Prison (de Chaumont)	0·169

In some places, notably mineral-water factories, where carbonic acid is largely made and used in the manufacture of aerated waters, the air often contains as much as from 5 to 10 parts per 1000; on the other hand, the air in a London street on a breezy day has been found to have as little as 0·36 per 1000. Carbonic acid in its pure form is fatal when present to the extent of 75 parts per 1000, while 15 parts per 1000 gives rise to giddiness, faintness, headache, and shortness of breath; anything below 10 parts per 1000 appears to produce no effect immediately on health. Its fatal quantities the action of carbonic acid is that of a narcotin poison producing insensibility and deep sleep. The amount of

carbonic acid given off by respiration is estimated by deducting the amount present in the outside air, or, what is usually the same thing, 0·04 per cent. from the total carbon dioxide present. Thus, if in a hospital ward or schoolroom the air was found to contain 0·78 of carbonic acid per 1000 parts of air, deducting 0·4 as being normally present in the atmosphere, we should have 0·38 parts per 1000 as a carbonic acid impurity due to respiration and other causes. We are all familiar with the heavy unpleasant smell or stuffy feeling present in all ill-ventilated or crowded rooms. In connection with this it has been observed that anything under 0·2 parts per 1000 over and above the 0·4 usually present in the air, that is, a total of 0·6 per 1000, is not associated with any atmospheric impurity capable of being perceived by the sense of smell. For this reason, this quantity is regarded as unavoidable and harmless, and, as such, a permissible impurity. The moment the carbonic acid exceeds this quantity, the accompanying organic and impure matters present in the air become perceptible; so much so that the following scale has been proposed, namely, "rather close" = 0·4; "close" = 0·6 (1·0 total); "very close" = 0·8 (1·2 total); beyond this amount the sense of smell does not seem able to distinguish. The temperature and degree of moistness of the air have an influence upon the readiness with which the smell of organic impurities are perceived. According to the late Professor de Chaumont, a temperature of 63° F. and 73 per cent. of humidity were conditions which gave the most accurate results, and, as such, might be accepted as the standards. In order to judge correctly the extent of atmospheric foulness by the sense of smell, it is necessary that the observer should have been at least some half-hour or so in the outer or fresh air, as the sense of smell is very rapidly dulled by foul air, so much so that the occupants of rooms containing impure air are rarely aware of its state.

Though the prolonged stay in crowded or ill-ventilated rooms whose atmosphere is markedly impure, as evidenced by a high ratio of carbonic acid, is invariably associated with headaches, faintness, giddiness, etc., it is not to the heat or even to the carbonic dioxide itself that these ill effects are due. These effects are really and generally recognized to be due partly to the reduction of the oxygen in the atmosphere, and partly to the presence in the air of the so-called organic and other hurtful products given off by the lungs and skin. The estimation of the amount of this oxygen reduction and general organic impurity is much less easy than the estimation of the presence of carbonic dioxide, and as the amount of this gas appears to bear a more or less constant ratio to these

other organic impurities, its estimation is usually accepted as the index of atmospheric purity or impurity. The precise nature of this organic matter present in air fouled by human respiration is undetermined. We know that, in addition to some 30 to 40 ounces of water, large quantities of organic matter are given off from the skin and lungs during twenty-four hours; the amount of this latter has never been precisely determined. In nature it is partly epithelium and other matters detached from the skin and mouth in a state of suspension, and partly of an organic vapour from the lungs and mouth. If collected from the air by condensation or by washing respired air in distilled water, it decolourizes permanganate of potassium, is precipitated by silver nitrate, blackens platinum, yields ammonia, and is, moreover, fœtid; thereby betraying its nitrogenous and oxidizable nature. It is readily absorbed by wool, feathers, damp walls and paper. It has a remarkable tendency to cling to parts of a room, diffusing slowly. Milk or other food left in contact with it readily becomes tainted, accompanied with a rapid growth of organisms. The general effect of air containing the organic matter produced by respiration is usually very marked upon human beings; producing heaviness, lassitude, headache, and often sickness. From experiments made upon animals, after the watery vapour and carbon dioxide had been removed and the organic matter alone left in the air, it was found to be highly poisonous, so much so that a mouse died in 45 minutes; while the historical episodes of the Black Hole of Calcutta, and the steamship *Londonderry*, in which 200 steerage passengers were forced on a stormy night to occupy a small cabin 18 feet by 11, and 7 feet in height, with the result that 80 persons were found dead the next morning, only too well emphasize its equally noxious effect on men and women.

The continuous breathing of a moderately vitiated atmosphere is not less hurtful to health. It induces a general lowering of the vital processes, with loss of strength and nutrition, to say nothing of an indirect influence towards both physical deterioration and general moral degradation. It is only too probable that to this cause, as much as to defective feeding, must be attributed the impaired vitality and health of many of the poorer inhabitants of our crowded towns and villages.

While, of the carbon compounds found as impurities in air, carbonic acid or carbon dioxide represents the main impurity due to respiration and combustion, there are several other gaseous impurities constantly added to the air as the result of the combustion of coal, coke, coal gas, etc. Among them are carbonic oxide, carburetted hydrogen, sulphurous acid, and sulphuretted hydrogen.

Carbonic Oxide is a gas produced by the combustion of carbon in an atmosphere of carbonic acid, and is frequently formed on the surface of charcoal stoves not exposed to air currents. This gas is extremely noxious, less than 5 volumes per 1000 being able to produce poisonous symptoms, such as dizziness, headache, confusion of ideas, with a feeling as if a tight band encircled the forehead and temples. In extreme cases, this gas causes suffocation by displacing the oxygen out of the red corpuscles in the blood. The presence of carbonic oxide is always a sign of imperfect combustion, such as occurs when coke is burnt in an open grate, and is especially apt to be generated by cast-iron stoves. This appears to be due to the fact that a portion of the carbonic acid evolved during the combustion of carbon is changed by heated iron into carbonic oxide, and that heated iron, more particularly cast iron, while generating and absorbing this gas by its internal surface, permits it to diffuse continuously from its external surface into the surrounding air. It is chiefly owing to this fact that the employment of stoves in this country has never been regarded with favour.

Carburetted Hydrogen, though often present as an impurity in air, as the result of combustion of coal, is a comparatively harmless gas. It is often present in small quantities in mines, and appears to do no harm. In large quantities, such as 300 parts per 1000, it seems to produce some poisonous symptoms, such as vomiting and convulsions. From its occasional presence in the air over marshes, this gas is often called "marsh gas." Another name for it is "methane."

Sulphurous Acid and sulphuretted hydrogen are, among other impurities, added to air by combustion processes. The former is a constant impurity in the air of coal and gas burning towns, where it often exists in sufficient quantity as to redden, after a few hours' exposure, moist blue litmus paper. The presence of this gas in the air of large towns is one of the chief causes of the difficulty experienced in cultivating shrubs or trees; while, too, when washed down by rain, it materially retards the growth of grass.

Sulphuretted Hydrogen, which is a disagreeably smelling gas, may be found in the neighbourhood of gasworks, chemical factories, sewers and marshes. In mines it often exists from the decomposition of iron pyrites, which is ferrous sulphide. If present in large quantities, this gas discolours paint, owing to the formation of lead sulphide. As a rule, this gas has no ill effects upon health, but a few cases have been reported, notably that of men digging out the Thames Tunnel, in which the continued breathing of this gas has given rise to serious symptoms.

In acute cases, these appear to be those of a narcotic and convulsive poison; while in chronic cases, more of the nature of anæmia, diarrhœa, and general sickness.

Suspended Matter.—The impurities of the air which we have so far considered are only gases, and, on the whole, generally diffused or distributed; but, besides these, there are certain impurities which are more or less solid, and only exist at or near the spot where the cause for them is to be found. We are all familiar with the fact that, if a beam of sunlight pass through a chink or crevice into a darkened room, its course is made visible to us by some of the light being reflected by minute particles of suspended matter. The particles which comprise this suspended matter, or solid impurities of the air, are of the most varied nature: some of them are inorganic, some organic, some absolutely harmless, some truly hurtful. Except in certain places, such as on the top of mountains or out at sea, it is difficult to find any air which is absolutely free from all suspended matter, while in towns and factories the atmosphere is usually heavily laden with many solid particles. How far these suspended matters or impurities in the air will affect our health, depends much upon their quality or nature, and not so much on their mere quantity; but this latter, in some cases, is not a negligeable point. Chief among the *inorganic* suspended matters of the air will be found fine grains or particles of sand, coal or carbon, clay, common salt, and oxides of iron. As a rule, these solid inorganic suspended matters of the air, consisting of dust of various kinds, though extremely injurious to health if in excess, are only so by virtue of their mechanical irritating influences upon the eyes and lungs. It is their physical conditions as to roughness, angularity, or smoothness, rather than their mere nature, which influences their power for evil. Various affections of the lungs, notably phthisis, or consumption, have been traced among classes of work-people as being due to the breathing in by them, during work, of the finer dust products of their particular trades or businesses. For instance, among tin-miners lung disease is prevalent, owing to the fine particles of tin-dust inhaled by these workers; similarly, the fine dust from iron mechanically irritates the air passages, and gives rise to considerable ill health among needle-makers, saw-grinders, and cutlers. So, too, among potters, a peculiar asthmatic cough is often set up in consequence of the continued breathing of the finer clay dust. The makers of cement, grindstones, and certain kinds of glass suffer in the same way. In white-lead works, the lead dust gives rise to colic amongst the workers, while workers in copper and brass foundries are subject to a special form of non-periodic ague, and among match-

makers the fumes and particles of phosphorus used in making matches, when inhaled, are apt to give rise to disease of the maxillary bones.

The *organic* suspended impurities of the air vary, even more than the inorganic, with the locality, both in kind and number. Among the more common are starch cells, pollen grains, and minute seeds of plants, pieces of wood, fine fragments of flax, wool, cotton and silk, together with fatty particles, scales of hair or skin, and germs of disease. The majority of these are, of course, harmless. That the disease known as hay fever or summer catarrh is produced in many by the pollen from grasses is too familiar to be doubted. In the carding-rooms of cotton, flax, wool and silk factories the finest dust from off the special fabrics is often so great and so irritating in nature in the atmosphere of the work-rooms that considerable ill-health results to those employed in them. Though it is somewhat disgusting to think that particles of fat and scales of hair or skin are floating about in the air, that such is the case is none the less true, and is, moreover, a not infrequent means of carrying disease from one person to another. Thus pus cells from ulcers and sores may give rise to a very infective form of inflammation of the eyes or even erysipelas, and the dried particles of expectoration from the lungs of those suffering from consumption, floating in the air, can convey that disease to those compelled to breathe such tainted atmosphere: in a similar way, the dried scales of skin from those sick with smallpox, scarlet fever, or measles may carry these diseases to the healthy. Though the germs of disease thus capable of being carried from one person to another by floating through the air can only doubtfully be supposed to find any nourishment and actually grow in the air, it is equally clear they can retain their power of growth for some time while thus suspended in the atmosphere. This is probably to be explained by the fact that these germs of disease, be they associated with bronchial expectoration or with scurf and scales from the skin, are really living organisms existing in the various forms of bacteria, bacilli, micrococci and other types of microscopic life. As such they differ widely amongst themselves, not only in form and shape, but as regards preparedness for development. Some are rod-like bodies, long and thin; others are but circular spheres of protoplasm; some are dry, others moist; some are fresh, others old. In some the hatching period is long, in others short: how soon or how readily they will infect any one depends largely upon the different degrees of resisting power of the particular germs and of the individual. A healthy subject may breathe in these germs and probably no ill effect follow, but if they find a place in some

system, weakened by faulty modes of life, the probability is they will give rise to disease.

Sewage Emanations.—Air rendered impure by emanations from sewage, whether from drains, sewers, or cesspools, is undoubtedly capable of giving rise to ill health, more especially in the form of sore throats (diphtheritic or otherwise), diarrhœa, and gastro-intestinal disturbance. The composition of such air is such that its oxygen is lessened, its carbonic acid increased, and that there is much organic matter together with varying amounts of sulphuretted hydrogen present. The numbers of micro-organisms present in the suspended matter of such air is not always increased. How far the bad effects following exposure to sewage-polluted atmosphere is due to any one individual impurity is uncertain, but the evidence is strong that either some specific poison is carried by sewer emanations to the general atmosphere, or else their effect is powerfully to predispose to disease. It is probable that sewer emanations differ largely in their specific powers for evil, according as to whether the generating sewer be adequately ventilated or not, as evidenced by the good health enjoyed by men working in well-ventilated and well-constructed sewers as compared with those employed in sewers which are ill ventilated and otherwise faulty.

Marsh Emanations.—In the neighbourhood of marshes the air is often impure: more especially being characterized by an excess of watery vapour, carbonic acid, carburetted hydrogen, hydrogen, and sulphuretted hydrogen. The organic matter is often high, while among the suspended impurities micro-organisms abound. Amongst these, several observers profess to have identified the particular organism said to be the cause of malarial fevers. Though these statements are not quite beyond doubt, there is every probability that the specific cause of ague and other malarial fevers does exist as a part of the suspended impurities in the air of marshes.

Impurities from Graveyards.—Though over vaults and graveyards in which burials have been excessive, or imperfectly performed, the air is apt, at times, to be somewhat impure from excess of ammonia, sulphuretted hydrogen and organic matter, no marked evidence exists that injury to health results from the air of ordinary burial-grounds. Grave-diggers, as a class, are healthy and longlived; but there is some evidence that the disturbance of old graves may give rise to disease, as shown by the fact that persons carrying out exhumations have, in many instances, suffered from febrile affections. Also, from the evidence gathered by the late Sir E. Chadwick, it would appear that increased sickness and mortality prevailed among persons living close to and

around overcrowded graveyards. No matter whether it be a human corpse or an animal carcase, there is little doubt but that, if such be imperfectly buried, and the gases, which are the natural result of decay and putrefaction, be allowed to escape from the soil, the air in the immediate neighbourhood is polluted sufficiently in many cases to affect health.

The air of **Brickfields** and **Cement Works**, though usually characterized by a distinct smell, cannot be shown to be sanitarily impure. The exact cause of the odours prevalent is not known, and though the air issuing from the chimneys of furnaces and kilns is rapidly fatal, so rapidly is it diffused and diluted that at a very short distance it is quite respirable. The chief evil of the smoke and gases escaping into the air from cement works appears to be its destructive effect upon all adjacent vegetation.

In former years, much atmospheric pollution occurred in the neighbourhood of copper, alkali and chemical works generally, from the pouring out of fumes of sulphurous, sulphuric, and hydrochloric acids, along with sulphuretted hydrogen and ammonia sulphide. At the present day this has to a great extent been remedied.

The Theory and Practice of Ventilation.

From the preceding pages we have learnt that, while the average composition of pure air is practically constant, the nature of the impurities in the atmosphere is less so. In the ordinary sense in which the term ventilation is used, we may regard it as the removal or dilution of all the impurities which can collect in the air of inhabited rooms. These impurities, we have seen, may be derived from various sources, such as respiration, exhalations from the skin, the combustion of fires and lights, the presence of filth, dirt or putrefying matter, and even the escape of emanations from sewers, drain-pipes, and other impurities under or outside our houses.

In practice, we may limit the term ventilation to the dilution or removal, by a supply of pure air, of the products of respiration and of combustion in ordinary dwellings, coupled in the case of hospitals with the additional impurities resulting from the presence of sick persons. For the removal of all other air impurities, ventilation ought not to be required, because, strictly speaking, these should be avoided by the exercise of due cleanliness and the maintenance of a proper system of drains and sewers, combined, moreover, with a general attention to the sanitary condition of the neighbourhood of our houses. Before proceeding, however, to determine how much fresh air is required for the above-named

purpose, and as to how this supply can be best attained, it is necessary to inquire with some detail what are the precise amounts of the impurities added to the air of our houses as the results of both respiration and artificial lighting and warming. To a large extent these latter may be ignored, as the products of the combustion of coal, used in artificial heating, escape for the most part by the flue of a stove or by the chimney of an open grate, and as such, do not materially add to the contamination of the atmosphere of a room; it is therefore unnecessary to enter into any great detail regarding them.

Impurities due to Respiration.—It will be a material aid to our conception of the amounts of the impurities added to the air by respiration, if we recall the facts that while the air breathed into our lungs contains about 79 per cent. of nitrogen, 21 per cent. of oxygen, and 4 parts in 10,000 of carbonic acid, the air breathed out by the lungs contains 79 per cent. of nitrogen, about 16 per cent. of oxygen, 3 to 4 per cent. of carbonic acid gas, and some $1\frac{1}{2}$ per cent. of watery vapour, the remainder consisting of organic matter. In other words, this means that the oxygen has been lessened by about one-fourth, the carbonic acid increased just about one hundred times, with the watery vapour, ammonia, and organic matter also increased.

A healthy adult man at rest breathes from 14 to 18 times a minute, and allowing that at each inspiration 25 cubic inches of air are taken in, the total quantity of air which passes into and out of the lungs in the twenty-four hours is about 686,000 cubic inches or 15·6 cubic feet in each hour. This amount is, however, largely increased by exertion, and may, in the case of a man doing great labour, reach as much as some 1,600,000 cubic inches in the same time. If we assume that the expired air contains only 4 per cent. of *carbonic acid*, the average man at rest evolves nearly 16 cubic feet of this gas in the twenty-four hours, or 0·66 cubic feet per hour; during hard work the amount evolved is something like 37 cubic feet in twenty-four hours, or say 1·6 cubic feet per hour.

The quantity of *watery vapour* given off from the body is greatly influenced not only by the different degrees of muscular exertion and repose, but also under the ever-changing degrees of moisture of the atmosphere. Speaking roughly, 10 ozs. are given off by the lungs and some 20 ozs. by the skin in the day. This is equivalent to about 550 grains per hour. If we assume the average temperature of occupied rooms to be 60° F., this means enough moisture is given off by the human body every hour sufficient to saturate 90 cubic feet of air. It is this tendency to become saturated with moisture from the lungs and skin that makes the air of crowded and unventilated rooms so uncomfortable.

Carnelley's experiments show that for every part of carbonic acid found in the air, 2·7 volumes, or 1·1 part by weight of moisture have been given off by each person inhabiting the room.

As already explained, although the carbonic acid added to the air by respiration and other processes is not of itself a very great impurity, yet it occurs in such constant relationship with the more important and potent organic matter as to be taken and accepted as the most convenient index of the amount of the general impurities added to the air by respiration. The amount of this gas, then, given off daily by an ordinary man in repose may be taken to be some 16 cubic feet, or 0·66 cubic foot per hour; in light work it is about 0·95 cubic foot, and in harder work from 1·6 to 1·95 cubic foot per hour. In the case of females, the figure is about 0·5 cubic foot, and for a child 0·3 cubic foot; or, as an average for a mixed community, 0·6 cubic foot may be accepted.

Impurities due to Artificial Lighting.—Turning now to the question of the precise amounts of impurity added to the air consequent upon artificial lighting, we find that the chief sources of light are candles, oil, and coal gas, and that the chief products of the more or less complete combustion of these illuminants are carbon dioxide and water, with the addition, in the case of gas, of several products of the combustion of sulphur. Now, the unit adopted in this country for the measurement of all lights is a sperm candle of a size known as "sixes," burning 120 grains per hour, and which gives a light known as "one candle power." Such a candle, on analysis, is found to contain—

Carbon	80·0 per cent.
Hydrogen	13·0 ,,
Oxygen	6·6 ,,

and on complete combustion yields equal volumes of carbonic acid and water to the air, namely, 0·41 cubic foot.

The French unit of light is the light given out by one Carcel burner, and equals 9·3 English standard candles.

What is known as Mr. V. Harcourt's standard flame gives a light equal to that of one English standard candle. It consists of an air-gas flame, $2\frac{1}{2}$ inches in height, rising from an opening $\frac{1}{4}$ inch in diameter. The flame is that of a mixture of air and pentane: 576 volumes of air being mixed with one of liquid pentane at 60° F.; or, if both are in the form of gas, 20 of air to 7 of pentane. Pentane is a hydrocarbon occurring in petroleum and in the light oil obtainable from Cannel coal.

Although various kinds of oil have been employed for illuminating purposes, paraffin, owing to its cheapness and high

illuminating value, is the only one in extensive use. Ordinary paraffin, on analysis, gives the following composition—

Carbon	86·0 per cent.
Hydrogen	14·0 ,,

When burnt in the better kinds of lamp, the average consumption per candle power of this oil is just 62 grains per hour, giving off on combustion in that time 0·28 cubic foot of carbonic acid and 0·22 of a cubic foot of water vapour. Formerly, rape-seed or colza oil was largely used for lamps, but now it is replaced by the mineral oils, paraffin and petroleum. Colza oil is remarkably safe, but is expensive, and needs a special lamp for its use, owing to its viscid nature and the difficulty in getting it to ascend the wick.

All oil-lamps should have a suitable reservoir for the oil. This should always be made of metal and not of glass or china, as these latter break easily and cause the oil to escape. The reservoir ought to hold at least half a pint of oil for each wick in the lamp. It should never be filled quite up to the top, nor be allowed to burn quite dry. If too full, the oil may overflow and catch fire; or when burnt to the last drop, the smouldering wick may set fire to an explosive mixture of oil-vapour and air which tends to collect inside the empty and hot lamp. Much of the success of oil-lamps depends upon the proper regulation of the draught to the flame by the length of the chimney and the placing of a suitable inlet for air through a perforated metal below. These are points usually seen to by the makers. Defects of this nature check complete combustion of the oil, and are the cause of the lamp smelling. All lamps should be provided with a patent extinguisher.

The chief popular illuminant is gas. Ordinary gas is obtained by the destructive distillation of coal, free from contact with the air, and consists of a mixture of several gases, varying largely, of course, upon the kind of coal used and the methods of purification. The following statement of the analysis of two London gases made by Prof. Lewes may be accepted as fairly representing the composition of coal gas generally—

	South Metropolitan Gas Company.	The Gaslight and Coke Company.
Hydrogen	50·16	53·36
Saturated hydrocarbons . .	36·25	32·69
Unsaturated ,, . .	3·50	3·58
Carbon monoxide . . .	5·68	7·05
Carbon dioxide	0·00	0·61
Nitrogen	4·10	2·50
Oxygen	0·31	0·21
	100·00	100·00

Every cubic foot of ordinary coal gas yields on combustion roughly half its own volume, or 0·52 cubic foot of carbonic acid and 1·3 cubic foot of watery vapour; whilst the lighting power of gas per cubic foot depends, of course, upon the particular burner employed.

Speaking generally, there are two principal kinds of burners in use, namely, the Argand and the flat-flame burners. The Argand, in its usual form, is particularly useful for common or low illuminating gas. The ordinary Argand burner consists of a hollow ring, from the upper surface of which the gas escapes by a number of small holes of varying diameters, the most highly illuminating gases requiring the smallest apertures (Fig. 1). In these burners, a circular flame is produced, which needs to be protected with a glass chimney, by which the admission of air is regulated. The illuminating power of these burners is that of 30 candles, with an hourly consumption of something like 8·83 cubic feet of gas. For their proper use, a regular and somewhat low pressure of the gas is essential.

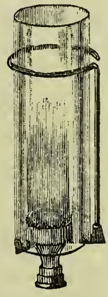


Fig. 1.—Argand Burner.

Flat-flame burners are of two chief kinds, known respectively as the fish-tail and the bat's-wing. The fish-tail (Fig. 2) consists of an iron nipple perforated by two holes, drilled so that the jets of gas are inclined towards each other at an angle of 90°. A flat

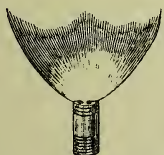


Fig. 2.—Fish-tail Burner.

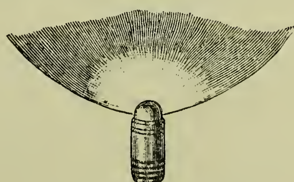


Fig. 3.—Bat's-wing Burner.

flame is thus produced, and somewhat resembling the tail of a fish. The bat's-wing (Fig. 3) consists of a similar nipple perforated by a fine slit, giving a flat, fanlike flame. In the best forms of all kinds of burners now in use, steatite or pottery (adamas) tops are employed. The common metal and steatite burners in use permit the current of gas to strike against the orifice without any control or regulation, but in the numerous patented forms of both fish-tail and bat's-wing burner, a certain mechanical obstruction or governor is inserted, which breaks or retards the gas current, to ensure more complete combustion. The illuminating power of a good fish-tail or bat's-wing burner equals 16 candles,

with an hourly consumption of something like 4 or 5 cubic feet of gas per hour; but the great majority of flat-flame burners in common use of the size known as 4 or 5, and popularly supposed to consume respectively 4 and 5 cubic feet of gas per hour, really consume nearly double that amount of gas, and at the same time yield an extremely low degree of light.

Assuming the use of ordinary 16-candle gas, the following table gives the illuminating value yielded by ordinary burners for each cubic foot of gas which they consume, as estimated by Professor Lewes:—

Flat-flame No. 4	1·9	candles.
,, ,, 5	2·1	,,
,, ,, 6	2·5	,,
London Argand	3·3	,,
Siemens' Regenerator	10·0	,,

The actual products of combustion given off by gas will, of course, vary much with the quality of the gas used and the completeness of the process. The usual products of the combustion of gas are: carbonic acid, carbonic oxide, compounds of ammonia, watery vapour and various compounds of sulphur. These latter, if present, are particularly injurious to health, but there is reason to believe that their existence in gas-lit rooms has been much exaggerated. For every 100 cubic feet of gas consumed, containing 20 grains of sulphur, there would be 0·032 of a cubic foot of sulphur dioxide formed, while with an impurer gas containing 30 grains of sulphur per 100 cubic feet, the sulphur dioxide resulting would amount to 0·048 cubic foot. Except under very exceptional circumstances, ventilation would reduce these quantities in nearly the same ratio as the carbonic acid, the total volume of sulphur dioxide due to the combustion of the gas being reduced to very minute traces, or something like 0·0625 grains of sulphur as sulphurous acid per 100 cubic feet of air. The presence of undue quantities of sulphurous acid in the air as the result of burning gas is chiefly productive of injury to health owing to the fact that by combining with the moisture and oxygen present in the atmosphere it becomes at once converted into sulphuric acid. This contingency is likely to be of rare occurrence in inhabited rooms, as it cannot take place unless the percentage of water vapour present in the air be at saturation point, an event of most unlikely occurrence.

If we adopt, as is usual, the amount of carbonic acid yielded as our measure of vitiation of the atmosphere, we find that each cubic foot of gas burnt per hour on an average vitiates as much air as would be rendered impure by the respiration of an individual;

for, as has already been stated, an adult exhales 0·6 cubic foot of carbonic acid per hour, and 1 cubic foot of ordinary gas yields on combustion 0·52 cubic foot of carbonic acid.

The relative amounts of oxygen removed from the air and carbonic dioxide and water vapour yielded by various forms of artificial light in order to give an illumination equal to 16 candles, is given in the following table, in which is also incorporated the number of adults who would exhale the same amount of carbonic acid in the same time.

	Sperm candles.	Paraffin oil.	Gas burned in	
			Flat-flame burners.	Argand burners.
Amount burnt	1740 grs.	992 grs.	5·5 c. ft.	4·8 c. ft.
Oxygen removed	9·63 c. ft.	6·24 c. ft.	6·50 c. ft.	5·75 c. ft.
Moisture produced	6·56 c. ft.	3·50 c. ft.	7·35 c. ft.	6·40 c. ft.
Carbonic acid produced	6·56 c. ft.	4·45 c. ft.	3·50 c. ft.	2·50 c. ft.
Air vitiation equal to adults	11·0	7·5	5·0	4·5

If we know, therefore, the amount of impairment and vitiation of the atmosphere produced by one gas-burner, lamp or candle, it is easy to arrive at the relative contaminating effect which the various artificial lights produce on the air of a dwelling-room. It follows, therefore, that a system of ventilation designed for a room when no artificial light is used, cannot be expected to be successful when a number of candles, lamps or gas-jets are burning. Although the contaminations, especially in the case of gas, are very great, it is estimated that for their proper dilution the amount of fresh air supply in relation to the carbonic acid evolved need not be so great in their case as for breath impurities, a supply of 900 cubic feet of fresh air for every cubic foot of carbonic acid per hour, evolved by the light, being deemed sufficient, and as every cubic foot of gas evolves 0·52 cubic foot of carbonic dioxide, it results that, for every cubic foot of coal-gas burned, something like 450 cubic feet of fresh air should be supplied per hour in addition to those needed to dilute the respiratory impurities.

As judged by the rules already laid down that the vitiation of the air of any limited space, such as a room, is measured by the amount of oxygen used up and carbonic acid generated, it appears that candles are most injurious to health and comfort, oil-lamps less so, and gas the least of all. Practical experience does not bear this out, since the discomfort and sense of oppression felt

by the use of gas in rooms is much greater than that following the use of oil or candles. The explanation of this discrepancy between science and everyday life probably is that, in attempting to light a room with either candles or oil, we are content with much less intense, but a more localized, illumination than when we employ gas. Say we have a room 16 feet long, 12 feet wide, and 10 feet high, and requiring for proper illumination a light equal to at least 32 candle-power. In such a room, if using candles, we should in all likelihood be content with a couple of candles placed near us to read or work, and not place 32 candles in different places to give a diffused yet sufficient light. It is obvious that with only two or three candles we should have less air vitiation produced than if 32 were burning.

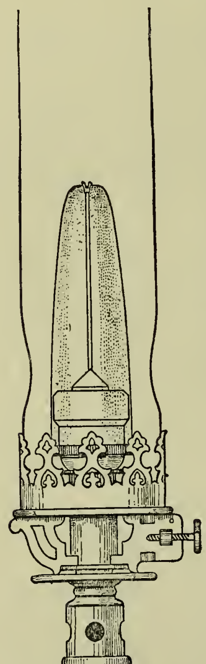


Fig. 4.—Auer's incandescent gas-light.

Illuminants not only yield actual impurities to the air, but also heat it. The amount of light evolved depends entirely upon the heat generated, simply because much of the light evolved is dependent upon the incandescence or excessive heating of the solid particles of carbon in the flame; and the greater the temperature to which these solid matters are raised the brighter the light. The later researches of Professor Lewes show that excessive saturation of the air and excessive production of carbonic acid have distinctly deleterious effects upon the illuminating powers of artificial light, though hardly of practical importance in dwelling-rooms.

The more recent improvements in gas lighting have done much to lessen the vitiation of the air by the products of combustion in dwelling-houses: partly by ensuring a more complete combustion of the gas and partly by arrangements for the rapid removal of their engendered impurities. The former is secured by arranging the burners upon the principle of the Bunsen burner, in which the gas being mixed with atmospheric air, the combustion is nearly perfect, and consequently no unburnt particles either of carbon or other matter escape unconsumed to foul the air. The incandescent gas-light as now in the market on Auer's system is based upon this principle, the light being derived from the incandescence or glow of a thin veil or mantle of asbestos gauze exposed to a Bunsen flame. This light (Fig. 4) is very

brilliant, economical in its consumption of gas, and hygienically sound; its practical defect is its great whiteness and dazzling illuminating power. On the same principle is devised the Regenerative burner in which the hot products of combustion are made to pass up between the incoming air and gas and thereby become heated to so high a temperature, sufficient to incandesce the carbon particles and obtain from them the greatest light. As illustrative of the second improvement in gas lighting, or that by which the impurities are at once removed, and not allowed to foul the air, is the "Globe" light, in which the gas-pipes come down from the ceiling through a tube. The burner, which is generally an Argand, and the lower end of the tube, are surrounded by a glass globe. The air is drawn in at the top of the globe, feeds the flame, and is then carried up the tube into the chimney of the room. The whole of this tube is surrounded by another tube, which it warms, and through which is drawn the impure air from the top of the room. A very excellent method of lighting is shown in Fig. 5 (after Galton), in which the gas-burner is placed in a globe and entirely cut off from the room and supplied with air directly from the external air, the products of combustion being also carried off directly. The fresh air comes through the grating at C, passing along the outer tube to the globe, and the foul heated air passes away through the inner tube. This method is, strictly speaking, only suitable for rooms otherwise efficiently ventilated.

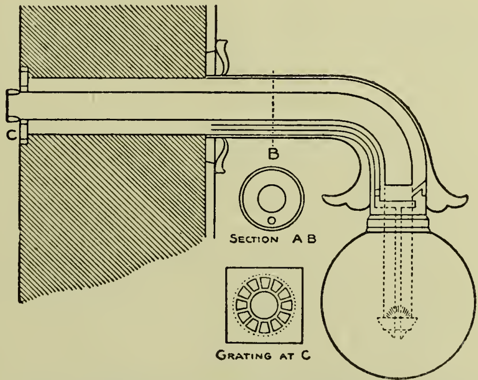


Fig. 5.—Diagram of a disconnected gas-light (after Galton).

The most hygienic form of light which can be imagined is, of course, the electric incandescent lamp, formed by a thread of carbon or platinum, rendered incandescent by means of an electric current, and enclosed in an hermetically sealed globe without any contact with the air, and consequently quite unable to in any way foul the atmosphere. Unfortunately, these lights are not yet within the reach of every one. The arc electric

light, which is not contained in a closed globe, is said to vitiate the air by the formation of nitric acid, but even if so, its effects in this direction are much less hurtful than gas, oil, or candles.

Quantity of Fresh Air needed.—Having now learnt something of the impurities poured into the air of our homes as the result of both respiration and artificial lighting, we have next to learn how much fresh air is required to dilute and remove those impurities, and how best this supply can be attained.

It has already been stated that an average adult exhales or gives off to the air 0·6 cubic foot of carbonic acid per hour, and since anything below or just up to this amount of carbonic acid in 1000 cubic feet of air in a room is indistinguishable by the sense of smell from the ordinary outer or pure atmosphere, that limit or amount of carbon dioxide can be regarded as the standard of efficient ventilation. But 1000 cubic feet of pure air contain 0·4 cubic foot of carbonic acid, therefore they can take up or receive 0·2 cubic foot more of carbonic acid and not contain an excess over the standard limit of 0·6 cubic foot. The quantity of 0·2 cubic foot of carbonic dioxide per 1000 of air, or 0·0002 per cubic foot of air is commonly spoken of as the *standard permissible impurity.* Based upon these facts, the late Professor de Chaumont suggested a very simple formula to determine the volume of pure air requisite each hour to keep the carbonic acid in the air of any inhabited room at this limit of 0·6 part per 1000 volumes.

Let **A** be the quantity of carbonic acid given off per hour per head. Let **B** be the proposed permissible maximum quantity of carbon dioxide in the air of the room per 1000 cubic feet of air. Let **C** be the amount of carbonic acid present in 1000 cubic feet of fresh air. Let **D** be the amount of fresh air required per head each hour to maintain the standard quantity B, expressed in thousands of cubic feet. Then $\frac{A}{B-C}=D$, or $\frac{0 \cdot 6}{B-0 \cdot 4}=D$, and if we take B to be 0·6 cubic foot per 1000 of air, we get the formula to read thus : $\frac{0 \cdot 6}{0 \cdot 6 - 0 \cdot 4}=D$, or $\frac{0 \cdot 6}{0 \cdot 2}=3000$ cubic feet of air needed each hour per head.

If it be the case of an individual doing light work in a room, and giving off say 0·95 cubic foot of carbonic acid per hour, we should have $A = 0 \cdot 95$, and the formula stands as $\frac{0 \cdot 95}{0 \cdot 6 - 0 \cdot 4}=D$, or in other words, D would equal 4750 cubic feet of fresh air

required hourly in order to keep the impurity down to the standard limit.

The formula can be used in another way. Suppose the air in a room has been found to contain 1·2 volume of carbonic acid per 1000, that is, 0·0012 per cubic foot of air, and it is required to know how many cubic feet of fresh air have been hourly delivered per head. In this case, the actually observed air impurity, namely, 1·2, takes the place of the maximum permissible impurity; that is, B now equals 1·2, hence we get $\frac{A}{B - C} = D$, or $\frac{0{\cdot}6}{1{\cdot}2 - 0{\cdot}4} = D$, or $\frac{0{\cdot}6}{0{\cdot}8} = D$. That is, 750 cubic feet of air have been actually delivered per hour in the room.

By a transposition of the same formula we can calculate the probable condition of the atmosphere of a room into which a given quantity of air has been or is being supplied. The formula would then stand thus: $\frac{A}{D} + C = B$. If in a room containing 5 persons, each giving off 0·6 cubic feet of CO_2 hourly, we assume 1500 or 1·5 thousand cubic feet of air to have been supplied per hour and to represent D, we get $\frac{5 \times 0{\cdot}6}{1{\cdot}5} + 0{\cdot}4 = B$, or $B = 2{\cdot}4$; that is, 2 parts of carbonic acid per 1000 of air will be present in the air of the room over and above what is normally present in the outer air. In some cases, of course, A would not be represented by 0·6 cubic foot, as say, in the case of an adult man doing hard work; the amount of carbonic acid given off by him per hour would be as much as 1·96, or nearly 2 cubic feet, and in the case of children, might be as low as 0·4 per hour. The general statement, however, of the formula remains the same.

A consideration of these facts indicates that if we wish to keep the air of our homes at the standard degree of purity, it should not contain more than 0·6 part of carbonic acid in 1000, or 0·2 part in 1000 over the average in samples of ordinary air. Further, in order to keep the carbonic acid below 0·6 part per 1000, it is necessary to change the atmosphere by supplying fresh air, and this, as worked out, means a supply of 3000 cubic feet of fresh air every hour for each person. The following table gives the amounts of carbon dioxide given off by various persons per hour under varying conditions, and, corresponding to them, the quantities of fresh air theoretically needed under those circumstances to maintain the air at standard purity:—

	CO_2 given off per hour in cubic feet.	Fresh air needed hourly per head in cubic feet.
Adult male in very hard work . .	1·96	. . . 9800
,, ,, in light work . . .	0·95	. . . 4750
,, ,, at rest	0·72	. . . 3600
Adult female at rest	0·60	. . . 3000
Children	0·40	. . . 2000
Average of a mixed community .	0·60	. . . 3000

Messrs. Carnelley, Haldane and Anderson, basing their opinion not only upon the average presence of carbonic acid in the air, but also upon the organic matter and number of micro-organisms, proposed that instead of taking 0·6 cubic foot of carbonic acid per 1000 as the limit, that the standard should be 1·0 for dwellings and 1·3 for schools. In the case of organic matter, that not more than two volumes of oxygen should be required for oxidation per million volumes of air, and that the micro-organisms should not exceed 560 per cubic foot of air.

In mines as much as 6000 cubic feet per hour have been proposed to ensure maximum energy in those working below ground. In hospitals and for the sick generally, the maximum amount of fresh air ought to be at least one-fourth more than that allowed in health. If 3600 cubic feet per hour be accepted as a general average supply for health, we may admit the needs of the sick to be at least 4500 cubic feet per hour.

As regards the amount of fresh air required for animals, the following table gives theoretical quantities of air as worked out by various observers :—

	Cubic feet per head per hour.	Cubic feet of space.
Cows	8000	 1600
Calves	3000	 600
Horses	8000	 1600
Dogs	500	 100
Pigs	3500	 700
Cats	400	 80

It is probable that these amounts are too small, at least 25 cubic feet per pound of body weight ought to be supplied, as, like human beings, all animals thrive best in well-ventilated places.

Cubic Air Space required.—Though theoretical considerations may indicate that certain quantities of fresh air are needed per hour per head in order to maintain the atmosphere at a degree of sweetness compatible with health, yet when it comes to actual practice, certain difficulties are met with. Experience shows that under the ordinary climatic conditions of this country, the air of a room cannot be changed more than three times an hour without causing much inconvenience by draught. This means

that if we are to have 3000 cubic feet of fresh air each hour, we must each have a cubic air space of at least 1000 cubic feet. If it be less than this, say, 100 cubic feet of space, then in order to deliver 3000 cubic feet of air hourly, the renewal of air will have to be thirty times in that period of time, and this we know, owing to the formation of draughts, would be unbearable unless the incoming air be warmed. At 60° F. air, moving at the rate of two feet per second, is barely perceptible; at three feet it is more so, and above this it becomes a draught. At 70° F. the velocity of the air current can be even greater without being noticed. The question arises, what then is the least amount of cubic space through which the standard quantity of fresh air can be passed without causing inconvenience from draught? By experiments made with the best mechanical means and artificial heat, Professor Pettenkofer determined that in an air-space of 424 cubic feet, 2640 cubic feet of air could be drawn through in an hour without perceptible draught; this was equivalent to a change of air at the rate of six times an hour. But in ordinary circumstances, and without artificial methods of warming the incoming air, a renewal of air in a room at the rate of six times an hour in this climate could not be tolerated. In fact, a change of air three or four times an hour is about as much as can be borne, and this brings us to an original air-space of close upon 1000 cubic feet. The moment we attempt to ventilate a small space, say 500 cubic feet, by ordinary or so-called natural means of ventilation, the difficulties arise not so much from the actual rate of movement of the general mass of air, as from the velocity with which the air enters at the openings and the nearness and relative position of these to the persons occupying the space. Taking a room of this size, with 3000 cubic feet of air being delivered per hour, and having an inlet or opening of 12 square inches, the rate of movement would be 10 feet per second, or nearly seven miles per hour; the room being so small, the rapid current of air could not be broken up, diffused, and mixed with the larger mass in the chamber sufficiently before striking its occupants and giving rise to a feeling of draught. If, of course, the room were just double the size, or 1000 cubic feet, the movement would be less felt.

Even with some artificial arrangements, experience goes to show that in small spaces, the air becomes much more impure than in large ones; the reason being that in small spaces, even if large quantities of fresh air are being supplied, little uniform diffusion occurs, as owing to the frequent establishment of direct currents between inlets and outlets, large amounts of the fresh air escape without being made use of; also that in small spaces

ventilation gets stopped much more readily than in larger ones, and if this occur, the ratio of increase of impurities is far greater in the small rooms than in the larger. The following table, by de Chaumont, well illustrates this, as do Wilson's experiments in the prison cells at Chatham, where he found the average amount of carbon dioxide in large cells to be 0·72, as compared with 1·044 in the smaller ones :—

	Ratios of impurity found in	
	Spaces of 1000 c. ft.	Spaces of 500 c. ft.
After 1 hour . . .	0·12 per cent. . . .	0·18 per cent.
,, 2 hours . . .	0·18 ,, . . .	0·30 ,,
,, 3 ,, . . .	0·24 ,, . . .	0·42 ,,
,, 4 ,, . . .	0·30 ,, . . .	0·54 ,,
,, 6 ,, . . .	0·42 ,, . . .	0·78 ,,
,, 7 ,, . . .	0·48 ,, . . .	0·90 ,,

The amount of air-space which these experimental and theoretical considerations indicate ought at least to be given to each adult, appears to be not less than 1000 cubic feet, but this is undoubtedly much in excess of what most people are able to obtain. In the majority of rooms occupied by the poorest classes, the cubic space available for each occupant is rarely more than 250 cubic feet, while in the lodging-houses of the larger towns the allowance is not more than 300 cubic feet. In Board Schools, the regulation minimum allowance is 80 cubic feet per head. For soldiers in barracks, 600 cubic feet is the least space allowed. In hospitals, the cubic space ought to be quite 1500 cubic feet, if not nearly 2000; and the minimum floor space 100 square feet. In all rooms with more than one occupant, it is necessary that a certain floor-space should be allotted to each person, for the purpose of allowing currents of air to remove emanations from one individual without interfering with his neighbour. For this reason, in all cases, whether private houses, barracks, hospitals, or other public buildings, a good rule is to secure as the lowest limit of floor-space an area not less than one-twelfth of the cubic space. Moreover, it is important to remember that mere height in a room is of no advantage unless combined with means for removing the heated air from the upper part, and that mere cubic space cannot take the place of change or renewal of air, for even the largest of air-spaces can only supply sufficient air for a limited time, after which the same amount of fresh air must be supplied. Thus 1000 cubic feet of space for one adult would be sufficient if the air in it were changed three times an hour, but in the absence of any renewal, 1000 cubic feet of air would only be sufficient for one person for 20 minutes. Of course, it must not be overlooked that the source from which supplies of fresh air is drawn must

be pure; and that, notwithstanding the fact of the standard quantity of air being delivered hourly per head, no claim could be made in such case for the existence of proper ventilation if the incoming volumes of air were in any way derived from contaminated or impure sources. In a similar way, attention needs to be directed to the actual temperature of the air entering a chamber; in summer it may need to be cooled as much as it requires to be warmed in winter, the reason being that the actual temperature of an air current is the main factor in our appreciation of its velocity. Owing to the fact that expired or foul air is warmer and lighter than pure air, it tends to rise to the upper parts of a room, for which reason, to ensure free ventilation, the outlets for impure air should be at or near the highest point, and the inlets, arranged so as not only to avoid draughts blowing upon the occupants, but also to secure equal diffusion of the air, should all be given an upward direction, whereby the tendency of the fresh masses of air, particularly if cool, to fall to a lower level, is minimized as far as possible.

We have already defined ventilation as the removal or dilution, by a supply of pure air, of all the impurities which can collect in the air of inhabited rooms or houses. We have also learnt that while the maximum permissible impurity of air, vitiated by respiration, is equivalent to the presence of 0·6 parts of CO_2 per 1000 of air, the maintenance of this standard under ordinary circumstances necessitates a supply of 3000 cubic feet of pure air per head per hour, and that for this purpose, and with ordinary means of ventilation, a space of at least 1000 cubic feet per head should be aimed at; though in everyday life, circumstances rarely permit this standard to be attained. The next matter, therefore, which demands consideration is how the ventilation of a room can be best secured. It is usual, and rightly so, to class the different methods of securing ventilation under two general heads: they are, the *natural* and the *artificial*. Now, all the methods of spontaneous diffusion produced by the unequal density of two columns of air, whether caused by chimney draughts or otherwise, belong to the former class; while the various methods of ventilation by means of pumps, fans, bellows, and various other contrivances, belong to the latter. The principles which bring about both these methods of ventilation are not difficult to understand, being based upon the action of well-known physical laws, all of which were discussed when we considered the physical properties of air.

Natural Ventilation.—This is carried on by the simple agency of gaseous diffusion, winds and the movements of air caused by inequalities of temperature. We have seen that every

gas diffuses at a rate which is inversely proportional to the square root of its density, and that while two gases of the same density show little tendency to mix, two other gases of different weights or densities would intermingle with great rapidity. For this reason, the air of rooms, being usually warmer than that outside, diffuses with rapidity through cracks and openings, and even through porous materials, such as sandstone, bricks, mortar and mud. To such an extent is this the case that experiments have shown that with a brick-and-mortar wall, a room containing 2700 cubic feet of air has its entire contents changed in an hour when the inside temperature is 65° F. and the outside just freezing. The amount of interchange between the inside and outside airs of rooms rapidly lessens, the more the temperature of the inside and outside agree one with the other; this explains why a room is often better ventilated in winter during a frost, with all its windows and doors shut and with a good fire in the grate, than in summer, with the windows wide open, and the inside and outside temperatures nearly identical. As a ventilating power, diffusion alone is found to be inadequate, mainly because all air impurities, as we know, are not gaseous, but partly molecular, and, as such, not affected by it.

The action of winds, as an agent in the production of natural ventilation, is partly by what is called perflation, and partly by aspiration. The wind is said to perflate if it pass freely through open doors and windows into a room; its ventilating action then is immense, but much less so if a through current cannot be obtained, as in narrow courts and alleys, or when pieces of furniture, curtains, etc., block the way. Mention has already been made of the ease with which air can pass through bricks, etc., but the action of the wind in this respect is probably not so powerful as generally believed. The ventilation power of winds by mere perflation is irregular, owing to the uncertainty of the air movements.

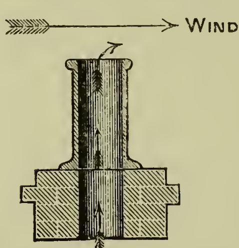


FIG. 6.—Draught up the chimney caused by the wind blowing over the top.

As illustrating the great aspirating power of the winds, as a ventilating agent, we may refer to the fact that winds blowing over the tops of chimneys or tubes cause a current of air to flow at right angles to themselves up the chimney or tube (Fig. 6); at the same time a similar wind can and does impede ventilation by either blowing against some opening or down a chimney. This reverse action can, of course, be obviated by placing a cowl or other similar contrivance on the top of the chimney. Many schemes

of ventilation fail owing to their having been designed with too little regard to the diversities of wind force and direction.

The primary force, which produces not only winds but the movement of all bodies of air, is the difference in their weights or densities due to inequalities of temperature. If a column of air contained in a tube or chimney be heated, it expands according to the ascertained law of Charles, which we have learnt is applicable to all gaseous bodies. This law, which regulates the movements of the air in any confined space, like a chimney or tube, when its temperature is higher than that of the outside air, depends really upon the following considerations: (1) Upon the difference between the temperature of the inside and outside airs. (2) Upon the area and other conditions of the openings through which warmed air can flow out and the cooler air flow in. (3) Upon the height of the ascending column of warm air.

If a column of air, say in a chimney, be 10 feet high, and have its temperature raised by a fire in the grate below, 20° F. above that of the air outside the chimney, then it will expand, for reasons already explained, $\frac{20}{491}$, or as near as possible $\frac{1}{24}$ of its bulk; as a result its specific gravity or density would be lessened, and it would require to be $10\frac{10}{24}$ feet or 10 feet 5 inches high to balance a column of the outer air 10 feet high when the temperature of the latter is 20° F. lower than the former; but as the height of the warmer column is exactly that of its containing chimney, which is only 10 feet high, the colder or outer column of air presses it up with a force proportionate to their difference in weight, and with a velocity equal to that which would be acquired by a body falling through a space equal to the difference in height that the two columns would occupy, if of equal weight, which in this case is 5 inches or 0·4 foot.

Now, by an application of the combined laws of gravity and the acceleration of forces, we are able to express the velocity in feet per second of a falling body by the formula $V = \sqrt{2gh}$ in which g is the velocity given to a falling body by the accelerative force of the earth's gravity; this, in our latitude, is 32·2 feet per second; h is the height through which the body falls. This formula, $V = \sqrt{2gh}$, which is sometimes called Montgolfier's formula, will then stand or read, $V = \sqrt{2 \times 32{\cdot}2 \times h}$; but that portion of the formula, $\sqrt{2 \times 32{\cdot}2}$ equals 8·2, or practically 8. Hence, we can simplify it and write $V = 8\sqrt{h}$, or say the velocity of the falling body equals eight times the square root of the height it falls. In the case we have supposed, 0·4 foot is the height of the effective descent or fall of the heavy column of colder air; hence, applying Montgolfier's formula, we can say $8\sqrt{0{\cdot}4} = 5{\cdot}056$

feet per second, or 303 feet per minute, will be the velocity with which the heated column of air would be drawn up the chimney. Very often in its application to ventilation problems the whole calculation is expressed by the formula being written thus—

$$V = \sqrt{2ga(t' - t)h},$$

in which the other symbols remaining as above, a is the coefficient of the expansion of air for each degree of temperature, t' the temperature of the heated column of air, and t that of the colder.

Having ascertained the exact velocity of the air-current, this, multiplied by the area of inlet, gives the cubical amount entering the space. Supposing, in the above example, the opening or throat of the chimney were one foot square, there would pass out or up that chimney 303 cubic feet per minute. This rate of flow is, however, subject to certain corrections, chiefly in consequence of friction arising from angular deviations of the chimney or tube. In straight tubes, the friction is found to be in all cases directly as the length of the tube and inversely as the diameter. In general practice, a deduction of from one-fourth to one-third of the velocity is necessary to compensate for these influences, and to obtain a true rate of outflow.

Two formulæ, proposed by the late Professor de Chaumont, and based upon Montgolfier's, are very convenient for determining the relation between the hourly delivery or output of air and the size of any opening or openings. Thus, one is—

$$\frac{D}{100f\sqrt{h(t' - t)a}} = \phi$$

In it, D is the delivery of air per hour in cubic feet; 100 is a constant; f is the coefficient of friction; h is the height of the heated column of air; t' is its temperature; t is the temperature of the outer air; a is the coefficient of the expansion of gases for each degree of temperature; and ϕ is the area in square inches of total inlets and outlets.

The other or converse one gives the delivery (D) per hour in cubic feet by either inlets or outlets stated in square inches, thus:

$$200f(\sqrt{h(t' - t)a}\phi = D.$$

In this, 200 is a constant, like 100 in the other formula. The constant 200 is used for either inlet or outlet alone, while 100 is used for inlets and outlets combined. These constants have reference to the expressions *time* and *space*, and are obtained by dividing the square inches in a foot into the number of seconds in an hour, thus, $\frac{3600}{144} = 25$, and multiplying this by $\sqrt{2g}$, or, as we know it to be, 8. The symbol ϕ signifies the area in square inches of either inlet or outlet alone.

There are various other ways of determining the direction and velocities of air-currents. Thus, by noting the direction of smoke caused by burning pieces of velvet; by floating hydrogen balloons so weighted as to be of the same specific gravity as the air; or, if such be available, by means of an anemometer. This latter is a very delicate instrument, consisting of four vanes attached to a spindle, the revolutions of which are recorded on a dial. If placed in an air-opening about $\frac{2}{5}$ of the diameter from the side, so as to obtain the mean velocity, the vanes are turned by the direct action of the air-current, and the velocity calculated from the linear movement as recorded on the dial-plate during some given period of time; this, multiplied by the sectional area of the opening, gives the cubical delivery or discharge according as to whether it be an inlet or an outlet. The actual velocity of air as it flows in and out of a room should not exceed 1 or at most 2 feet per second, simply because a low velocity is favourable to uniform diffusion of any incoming air through the room, and because a high velocity is apt to give the sensation of a draught. As explained, some allowance must be made for friction, particularly in outlets, and here the velocity should not exceed 3 to 5 feet per second. The particular velocity in any given case will naturally be regulated by the sizes given to the inlets and outlets, and on the quantity of air needed as indicated by the precise number of occupants, the amount of artificial lighting, and other special causes of air vitiation.

Having in the preceding pages learned something of the general laws and circumstances which govern the movements of air, as well as considered the amount of air to be provided, it is necessary now to discuss the various methods which have been adopted or proposed to practically apply them. Of all the methods of natural ventilation, the simplest and most obvious is that of more or less open doors and windows; but this arrangement, except in the warmest summer weather, causes draughts, and is unpleasant. To secure adequate perflation, all windows should, if possible, be placed on opposite sides of a room, while, too, each of such windows should be made to open at the top. Owing to air flowing against the body, at or even slightly above the temperature of a room, causing a sensation of cold or draught, it is necessary for comfort that air should be introduced and removed from inhabited rooms at those parts where it will not give rise to a sensible draught. In the large majority of houses, particularly those of the poorer and middle classes, even in these days, ventilation arrangements are either of the most crude and haphazard kind, or else absolutely wanting altogether. The greater number of living-rooms depend for their supply of fresh

air upon just so much as can find its way in through doors, windows, or through cracks and crevices around and under doors and windows, or even through the floor, and for the escape of foul air, upon what goes up the chimney, if a fire be alight, or what can get out through doors and windows; the general result being that either the chamber is so cold and draughty that no one can live comfortably in it, or so hot, close and stuffy, that health is affected.

All ventilation methods aim at avoiding these results, by providing, in the first place, inlets, or means of entrance for the fresh air, and outlets, or means of escape for the foul or impure air. It will be readily understood that all *inlets* or orifices by which cold fresh air is admitted should be above the level of the heads of those occupying a room, say 9 feet, and directed upwards to the ceiling, while the actual current itself should be as much broken up or dispersed as possible by means of trumpet-shaped openings, the smaller apertures of which are towards the outer air and the wider towards the room. If the inlets be intended for delivering previously warmed air, then they should discharge near the floor. The warming of air previous to its entering a room by an inlet is conveniently done, either by the use of an air-chamber placed behind a grate or stove, as in Galton's stove, or by the passage of it over hot-water pipes.

FIG. 7.—Hinckes Bird's Plan of Window Ventilation.

As to *outlets*, since the escaping of impure air is invariably warmer than the incoming or fresh supply, the right place for them is the top of the room, and in cases where the foul air is specially warmed, as over ventilating gaslights, the connection of the outlet tube with the chimney constitutes the best arrangement. In all cases, these structural devices, whether as inlets or outlets, should permit of their being kept free from dirt or otherwise getting blocked up.

Among the many devices for inlets of fresh air is the simple plan, suggested by Dr. Hinckes Bird, of raising the lower sash of a window by an accurately fitting block of wood, whereby a corresponding space is left between the meeting-rails in the middle of the window, through which entering currents of fresh air are directed up towards the ceiling (Fig. 7). With the same idea, others have proposed double panes of glass, an open space being left at the bottom of

the outer and at the top of the inner one. Similarly, a pane may be louvred, that is, strips of glass lying one over the other, and fixed on to a frame, which, by means of a lever, can be opened or shut at will (Fig. 8). Windows can be so made that, when they

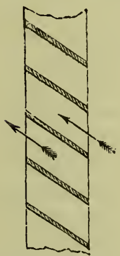


FIG. 8.—Louvre Ventilator.

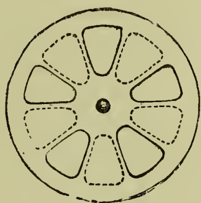


FIG. 9.—Cooper's Ventilator.

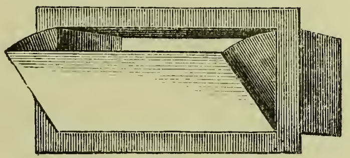


FIG. 10.—Sherringham Valve.

open, they slope into the room, or they can have a part of a pane to open or shut by a spring as in Boyle's or Cooper's ventilator (Fig. 9).

An excellent form of inlet is that known as Sherringham's valve (Fig. 10), which consists of an iron box, so made that the air enters from outside through a perforated brick or grating, and is directed up towards the ceiling by means of a valve which can be made to close or open by means of a balanced weight. The inside area of the ventilator is larger than the outer, consequently the air enters the room at a less velocity than at which it passed through the outer wall or grating. Another plan, advocated originally by Mr. Tobin of Leeds, is that of introducing the air through horizontal shafts under the floor, and then delivering it into the room through vertical tubes (Fig. 11), at different heights, varying from 6 to 9 feet from the floor. The currents of air issuing from these tubes ascend and then curve imperceptibly downwards. For public buildings, like churches or halls, the columns which support galleries may on this principle form convenient inlet tubes. These Tobin tubes are not very suitable for ordinary houses and dwelling-rooms, as they are difficult to keep

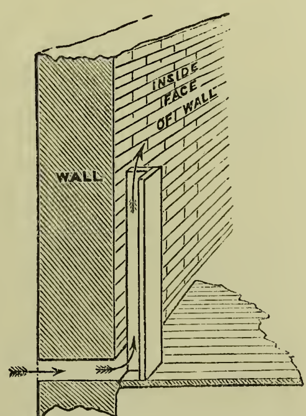


Fig. 11.—Tobin's Ventilating System.

clean, and often become clogged up by cobwebs, dirt and dust. They, moreover, do not readily become or act as outlets when occasion requires, which, being a conspicuous feature of the Sherringham valve, renders that form of ventilating agent practically the most convenient for everyday application.

Suitable inlets can be provided by what are known as air-bricks, of which probably the best types are those of Ellison and of Jennings. They are merely specially prepared bricks perforated with a number of holes, so cut that the inner aspects of the perforations have a larger diameter than the outer, whereby the velocity of the entering air-current is lessened. The wind blows through them, but with a variable movement. In Jennings's air-brick, the perforations are directed upwards, so that the entering air-current flows rather towards the ceiling than down towards the floor.

With all, or any of these simple ways of letting fresh air into rooms, it is presumed that equal facilities are offered for the escape of the foul air. In most rooms, particularly if a fire be alight, this will be done largely by means of the chimney connected with it, but in its absence may need to be accomplished by special outlets. The simplest form of outlet, other than a chimney, is a special shaft from the ceiling to above the roof; this is the principle adopted in the army for ventilating barrack-rooms and hospitals, combined with arrangements for admitting warmed air. The movement of air up such an outlet shaft will largely depend upon the aspirating action of the wind over its top, and upon the particular temperature inside it as compared with that of the outer air. Owing to the uncertain and disturbing action of these influences, these shafts do not always act as outlets, but in any case facilitate a continuous change of air, whichever way they happen to act. Down currents in such shafts can usually be obviated by placing a cowl or valve on its upper orifice, or by leading it up inside a chimney.

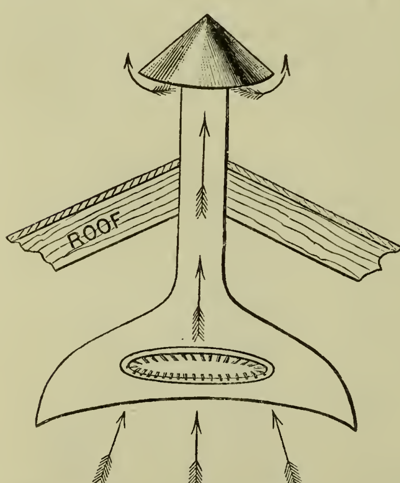


Fig. 12.—Ventilation by Sunlight Gas-burner.

Frequently so-called ventilating gaslights are used as outlets, in which the products of combustion, after being collected by means of a cover or bell-glass, are carried off by a tube which is itself often contained in a larger one. Owing to the heating of the inner tube, the space surrounding it and between it and the outer one acts as an extracting shaft for foul air. In theatres and other public buildings, advantage is taken of this method by using the Sunlight gas-burners (Fig. 12), which, in addition to lighting the building, act as extraction-shafts for removing the polluted air.

Another arrangement, known as Arnold's valve (Fig. 13), is designed to act as an outlet for foul air. It is usually placed in the wall of a room near the ceiling, so as to open into the chimney. The valve is so arranged as to swing towards the chimney, when the pressure or draught of the air is from the room

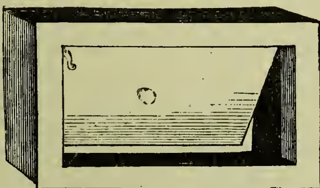


FIG. 13.—Dr. Arnold's Valve.

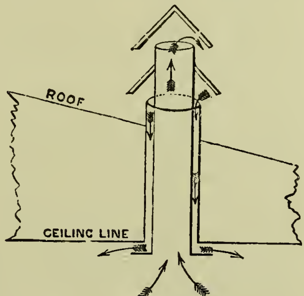


FIG. 14.—McKinnell Ventilator.

to the chimney; but when the pressure is greater from the chimney to the room the valve closes, and thus prevents the escape of smoke or air from the chimney into the room. These valves are sometimes objectionable owing to the noise they make.

An ingenious ventilator is that of McKinnell's (Fig. 14), which consists of two tubes, one inside the other, carried up through the ceiling of a room; fresh air passes down in between the two tubes, and by a flange on the inner tube is dispersed. The inner, or outlet tube, which is always made sufficiently large to equal in area the inlet, projects well beyond the other, both above and below, and effectively carries off foul or impure air. This is a very useful method of ventilation under certain conditions, but, like all others, is not universally applicable. On much the same principle, ventilating cornices are made, which consist of a double channel of perforated metal: by the lower channel cold fresh air is brought into a room, while by the upper one the fouled air is carried to the chimney or other outlet. Analogous to this plan is that of carrying along the cornice of a room, on three

sides, a perforated inlet tube, while on the fourth side is a similarly perforated outlet tube.

In other cases, by a like contrivance a fairly good cross-ventilation can be secured by means of a series of transverse ventilating boxes or tubes placed at regular intervals and close to the ceiling. These, running across the room from wall to wall, open into the outer air at each end by an air-brick. The sides of these tubes are made of perforated zinc, and to prevent the wind blowing right through, they are stopped or blocked in the centre by a partition. According as to whether the wind blows from one side or other, so one half becomes an inlet for fresh air, which diffuses gently into the room through the perforations, while the other half acts as an outlet for the fouled air.

In the employment of these various devices to secure natural ventilation, more particularly where the effect of differences in air densities dependent upon unequal temperatures is the controlling factor, it must not be forgotten that though theoretically the size of the openings, whether intended for inlets or outlets for any required change of air, can be obtained by the use of the formulæ given on page 36, in actual practice these cannot be fixed to meet all conditions. In this country, for the efficient ventilation of an occupied room, an allowance of 48 square inches per head, or 24 square inches of inlet and the same of outlet, is required. As a rule, the size of these openings should be in proportion to the size of the room; it is better to have openings too small than too large, and while the inlets and outlets can usually be of the same size, still no one individual inlet ought to be larger in area than 60 square inches, nor an outlet more than 144 square inches.

Artificial Ventilation.—For the production of artificial ventilation, two systems are in use: namely, ventilation by extraction and ventilation by propulsion.

The simplest example of ventilation by *extraction* is the action of an ordinary fireplace, which, by heating a column of air, causes its expansion, ascent and replacement by another but colder volume. The ventilation of theatres is largely carried out by utilizing the central chandelier and all the gas-jets, which being each placed under outlet tubes, by warming the vitiated air, cause it to expand and escape up the tubes which are so arranged as to all unite and empty themselves into a single large outlet, thus serving to carry off the products of both respiration and combustion. Mines are largely ventilated by means of a furnace at the foot of the upcast shaft, its supply of air being drawn down another shaft and then made to pass through all the

Art. by heat, steam & fan

workings on its way to the upcast by an ingenious arrangement of doors and partitions.

As typical of the various methods proposed for ventilating artificially large buildings, by means of extraction, may be mentioned the system of ventilating the Houses of Parliament, and that of Jebb for prisons. In the case of the Houses of Parliament, fresh air is made to enter the basement, where it is first washed or filtered through screens of moistened canvas, then passed over steam-pipes, by which it is warmed, and next conducted by shafts to spaces beneath the floors and benches of the rooms. The vitiated air ascends to the

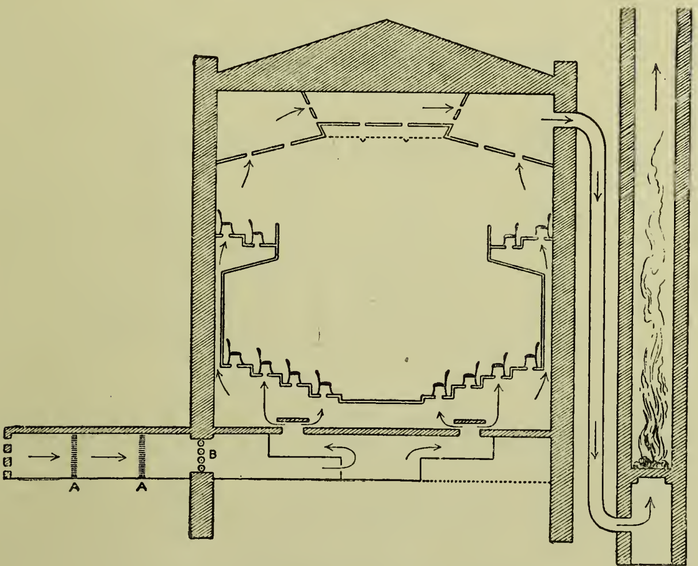


FIG. 15.—System of Ventilating the Houses of Parliament.

roof or ceilings, through which it passes by perforated openings, and is thence conducted by a shaft down to the basement of the clock-tower, where the flue of a furnace furnishes a powerful up-exhaust (Fig. 15). The power of the clock-tower exhaust is so great as to act equally well when the incoming air is not heated, but even actually cooled, as it is in summer.

Jebb's system for prisons consists really of the extraction of the foul air near the floor of the cells, and its admission at the ceilings. The idea is well shown in Fig. 16, in which it will be

seen that fresh air entering the basement is warmed by hot-water pipes; from there, by means of separate flues, built in the inner walls of the corridors, it ascends to each separate cell by an opening near the ceiling, while the foul air escapes or is sucked out near the floor level and made to ascend, by other flues, to the ridge of the roof. Its ascent is aided by a current of hot air from fires kept burning in the roof, and which, coupled with the

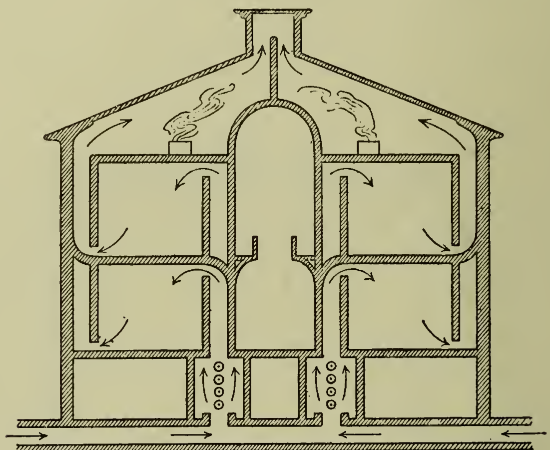


Fig. 16.—Jebb's system of Ventilating a Prison.

current from the basement fires, exerts a very powerful up-draught. The great objection to this system is that it is expensive in the consumption of fuel.

In the Bank of England, the cellars are ventilated in a somewhat similar way, the up-draught being kept going by means of gas-jets burning in the flues of chimneys or special shafts. Perhaps the most elaborate and complete system of artificial ventilation for a private house is that of Drs. Drysdale and Hayward, of Liverpool. In principle it is very similar to that in the Houses of Parliament, the kitchen being placed in a position to act just as the furnace in the clock-tower, and is, in fact, the only fire kept constantly burning. Of course, it will be readily understood that any such scheme as this is only feasible in compound buildings or residences of exceptional design, and, to be carried out economically and well, must be thought of while the house is being built, and not after it is built and finished.

On board steamships, a similar plan is arranged, the upcast

being a space round the boilers and funnel; and while a strong current of air rushes up this space, air to feed it is directed down the hatchways. The same method is turned to account in hotels and public buildings by the utilization of hot-water pipes to cause currents of air in suitable extraction-shafts.

As aids to extraction methods, various forms of cowls have been invented, but no one of them can be recommended as being absolutely successful. More successful is extraction by fans. A paddle-wheel-shaped fan, inclosed in a chamber, is placed in the roof of a building and conveniently driven by a gas-engine. By the revolutions of the fan, the foul air is drawn up from the apartments through ventilators placed near the ceiling into tubes, and by them conducted to an open-air outlet above the fan. Fresh-air inlets are of course provided near the floor levels of the room so ventilated.

In the case of ventilation by *propulsion*, the air is driven mechanically by either bellows, pumps, or fans into proper channels. This plan of artificial ventilation is more adapted for factories and workshops than for ordinary houses. In the former, besides for ordinary ventilation, currents of air are often required to blow away dust or suspended matters, for which purpose the openings need to be near the floor and not near the ceilings, as for ordinary vitiated air. Strictly speaking, what is called the propulsion method is an impulsion system, as by it fans are used to propel air into a basement chamber, from whence, after being heated over coils of hot-water pipes, it is carried by ducts to each room separately. These ducts open some 7 feet above the floor level, and as the velocity of the impelled air is considerable, it is diffused near the ceiling, and moves down through the room imperceptibly, to finally escape at the floor into vertical outlet shafts discharging at the roof. This method is common in French and American hospitals; while an analogous plan is in use in Liverpool, to ventilate St. George's Hall.

Though much less common than extraction methods, ventilation by propulsion has the advantage of precision and ease and certainty with which any given volume or required volume of air can be treated or used; it, however, is expensive. Owing to the absence of control over the sources from which air is sucked in extraction methods, due to the readiness with which air rushes in at all available apertures, the supplies of air under these circumstances are occasionally drawn from objectionable places. With care, however, provision can be made to either warm, cool, wash, or filter the air at suitable points.

On the whole, the advantages of artificial ventilation are great, being mainly due to its facility of management and constancy

under varying conditions. For factories, workshops, ships and wherever there is machinery, artificial ventilation, whether by extraction or propulsion, is certainly the most economical and convenient. On the other hand, public buildings, such as prisons, theatres and hotels, commonly require to be ventilated by some mechanical arrangement based upon the utilization of all fires and gas to work an exhaust shaft. In private houses, the use of ventilating grates and stoves, or some of the simpler plans of ventilation, should suffice to keep the air pure, but no hard-and-fast rule can be laid down, each case requiring to be considered intelligently on its merits.

Warming and Heating.

This subject is very closely connected with ventilation, but for its thorough comprehension some knowledge is necessary of the laws of heat. Now, heat is distributed in three ways: these are by radiation, by conduction, and by convection.

Radiation of heat is not only the most common but the most wasteful. This kind of heat is propagated in straight lines in all directions with equal intensity, the effect lessening according to the square of the distance; thus, if the heat at one foot distance from a fire be 1, then at ten feet it will be one hundred times less. If radiant heat fall on a solid body, it is reflected in the same way as light, but some of the heat is absorbed, the amount reflected and absorbed being in inverse proportion to one another, and largely dependent upon the surface, colour and nature of the body.

Heat is **conducted** through all solids, but to a very limited degree only by liquids and gases. The best heat conductors are the metals, then stone, next wood, and least of all wool or silk. Bodies which are good conductors rapidly give off their heat to the surrounding air or to anything in contact with them; in like manner, if colder, they withdraw heat from other bodies. Porous materials, like felt, are extremely bad conductors of heat.

The **convection** of heat is that mode in which heat is propagated in liquids and gases, and is dependent upon that characteristic of those bodies which allows the portions of them which have been heated to expand and rise, their place being taken at once by colder parts. A sort of circulation of the water or air is set up, and the whole mass soon warmed.

Disregarding any particular variations in the source of heat, that is, whether from coal, coke, wood, etc., we can say that the

principal methods of warming and heating houses or rooms may be classed as either open fires, closed fires or stoves, and pipes containing either heated air, hot water, or steam.

Open Fires.—Long-established custom and prejudice have caused open fires to be the means of heating nine-tenths of the houses in England, notwithstanding the fact that they are really the most costly and imperfect means of heating, as evidenced by the fact that they only render available 13 per cent. of the total heat capable of being yielded by coal or coke, and only 6 per cent. of that by wood, the rest being lost in the air, or escaping as unconsumed carbon up the chimney. The actual heating effect of open grates is most unequal in different parts of a room, but on account of the cheerful light which they emit, and the ventilation which they ensure, open fires will always be preferred as the pleasantest and healthiest mode of heating. Following Teale, the chief practical points to be aimed at in making open fireplaces, may be summarized as follows :—(1) Use as little iron, but as much fire-brick, as possible. (2) The back and sides should be made of fire-brick. (3) The back of the fireplace should lean or hang over the fire, while the throat of the chimney should be contracted. (4) The bottom of the fire should be deep, from before back. (5) All slits in the bottom of the fire should be as narrow as possible. (6) The bars in front should be narrow. (7) The space beneath the fire should be closed in front by a close-fitting iron shield or "economizer." The object of this latter point is to secure as complete combustion as possible of the fuel at the bottom of the fire by the exclusion of cold air. In the use of an ordinary open fireplace, about one-eighth of the heat given off by the fuel consumed is utilized on the air of the room. All open grates should be made so as to have the fuel slowly and completely consumed, while the draught up the chimney should not be in excess of ventilation requirements. Most English grates consume 8 lbs. of coal in an hour: for the combustion of each pound of coal 300 cubic feet of air are needed; this means 2400 cubic feet hourly, but in actual practice something like 20,000, or even 40,000, cubic feet of air pass up the chimney; in which case, supposing the room contains 4000 cubic feet of space, the air in it gets changed from 5 to 10 times in the hour according to the strength of the fire. If the incoming air were warm, this liberal ventilation would be excellent, but, unfortunately, it rarely is so, but is in the main quite cold, finding entrance through the floor, or by chinks round the windows or beneath the door.

Stoves, as usually made, are of cast iron, and are essentially apparatus for heating with a detached fire, so placed that the pro-

ducts of combustion escape by an iron flue or chimney to the outer air, while the main portion of the generated heat radiates in all directions round the stove. At the lower part is usually a draught-hole, by which the air necessary for combustion enters. Owing to the less waste of heat by these means of warming than by open grates, this mode of heating is the more economical, but by no means so healthy as that by ordinary fireplaces, because their ventilating power is so much less. Stoves are often objectionable owing to their making the air hot and dry, but this can be obviated usually by placing vessels of water upon them. They often, too, emit a bad smell, due generally to the decomposition of organic matter present in the air, by contact with the heated sides of the stove and chimneys, or occasionally from the diffusion of carbonic monoxide and other gases through the heated sides of the stove. These objections can in great measure be obviated by the use of wrought iron, and having the joints more securely riveted than is commonly the case; or the stoves may be lined with firebrick and covered with tiles, as is seen in the better class of houses on the Continent.

Gas, of later years, has come into very general use both for warming and cooking; it is admirably adapted for the latter, being not only cleanly but economical. For heating purposes, it has not made the progress which its many advantages deserve, probably owing to defective forms of stove used. Speaking generally, there may be said to be four common forms of gas-stove in general use: these are (1) reflector stoves, (2) condensing stoves, (3) asbestos or hollow-ball refractory fuel stoves, (4) Calorigen stoves.

The *Reflector stove* has usually a naked gas-flame, backed by a glass or metal reflector. It is bright and cheerful-looking, but gives out little heat, and unless provided with a flue—which more often than not is not provided—very considerably adds to the vitiation of the air.

Condensing stoves are those so constructed that the water vapour, which is one of the products of gas combustion, is condensed by passing through upright tubes, and then caught in a tray beneath. This condensed vapour naturally carries down with it some if not all the sulphur products, but fails to remove any of the carbonic acid which, notwithstanding all statements to the contrary, really escapes into the room. For this reason, this stove always requires a flue; unfortunately, its heating powers are small.

Stoves fitted with *asbestos fibre* or refractory hollow-ball fuel, and lighted by Bunsen or Argand burners, are relatively popular, owing to the fact that the fuel is rendered incandescent, with a

close resemblance to the glow of an ordinary coal fire. These stoves yield radiant heat only as a rule, though a few are made with attached hot-air chambers, to give off heated currents of air. These are in the main good stoves, but somewhat extravagant as gas consumers, and always needing a flue to carry off products of combustion, and which as well takes off much of the heat which they produce as so much waste.

The essential defects of all the three preceding forms of gas-stoves are a disproportionately low amount of heat gained as compared with the high expenditure of gas, due mainly to a failure to rob the products of combustion of their heat before they escape out of the stove in as large a degree as is consistent with ensuring their escape from it. It is at once obvious that

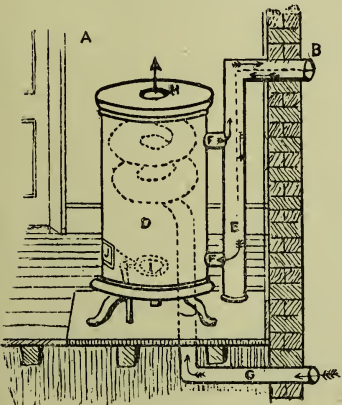


FIG. 17.—George's Calorigen.

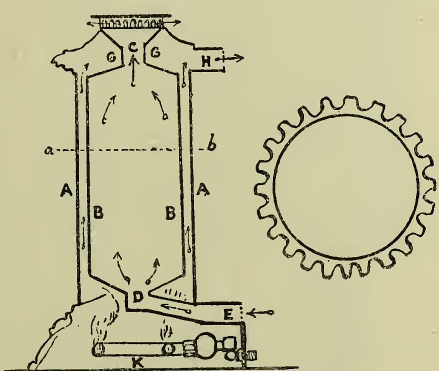


FIG. 18.—Bond's Euthermic Stove.

this can be most effectively secured by bringing the heated combustion products into contact with a large metallic area so arranged that the heat which it absorbs shall be given off either by direct radiation or by the conducting influence of air-currents flowing over it. It is the application of this idea, of allowing a current of air previous to being discharged into a room, to be warmed by contact with and circulating over the flue or tube conveying the heated products of the combustion of a gas-flame, that constitutes the principle of construction of the so-called Carlorigen stove of Mr. George and the "Euthermic" stove of Dr. Bond.

By a reference to Fig. 17, it will be seen that in George's *Calorigen*, the body of the stove is made of rolled iron and contains a coil, G H, of wrought-iron tubing open at the top H; this

at its lower end is carried through the outer wall either above or below the floor to a point from which an appropriate supply of fresh air can be obtained. The cylindrical metal body of the stove has connected with it two pipes, one an upper one for carrying away the products of combustion into the outer air, while the lower one brings in fresh air to support combustion. The action of the stove will be evident; the heated combustion products not only heat the outer metal case, and through it the air in contact with it, but also heat the current of air constantly passing up through the coiled tube into the room.

The *Euthermic* stove, shown in Fig. 18, consists of a corrugated metal cylinder which, as in George's Calorigen, constitutes the stove body; above this, it discharges into a flue for the escape of combustion products, while below it is open for the location of a gas-jet and a supply of air. Inside this metal cylinder is a metal drum, having an inlet tube, E, below, for bringing fresh air, and open at its upper end, to allow of air which is heated in its passage through the stove to escape into the room. The figure showing a transverse section of the stove well indicates the drum inside the corrugated cylinder, whereby a considerably increased superficial surface is secured not only for the heated products of combustion to yield their heat into the room direct from the outer surface of the corrugations, but also from the inner surface of the contained drum to the air within it.

Although both these stoves possess considerably greater heating powers than any others, the Euthermic is for choice perhaps the better of the two, mainly on account of its open bottom rendering the stove a true ventilation agent, inasmuch as the air needed for the gas combustion has to be drawn from the room itself, and by that means favours a continuous change of air through it. This is not well secured by the Calorigen of George, because it is closed below, and all movement of air through its coiled tube, G H, is largely dependent upon the conditions which exist in the room for allowing air into and out from it, and is but slightly influenced by the pure and simple action of the stove itself. As means of heating by gas, all stoves made upon the principle of these two are obviously preferable to any constructed on other systems.

Hot Air, obtained by driving air over hot bricks or pipes, is occasionally introduced into rooms and public buildings for heating purposes, by means of mechanical arrangements such as fans, as used in artificial ventilation methods. This is very efficient as a way of combining warming with ventilation, but is very costly. A modified application of this method has been

designed by Sir Douglas Galton in the form of a stove, in which the fire which warms the room is also utilized to supply warm air. Figs. 19 and 20 show the existence of an air-chamber behind the grate, in which the air is warmed by the iron back, upon which several broad iron flanges are cast so as to obtain a large surface of metal to give off heat. The fresh air is obtained

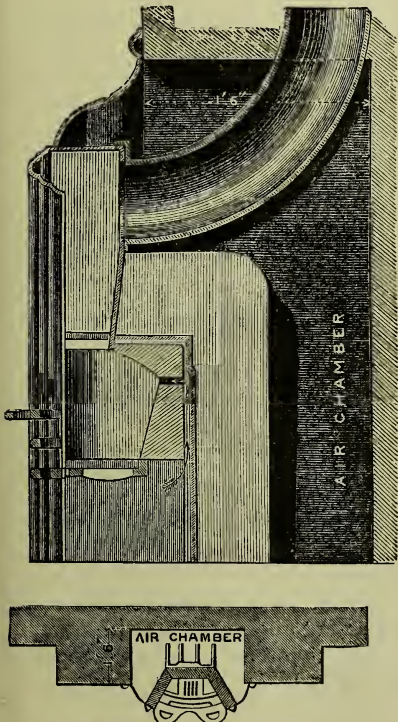


FIG. 19.—Section and Plan of Sir Douglas Galton's Grate.

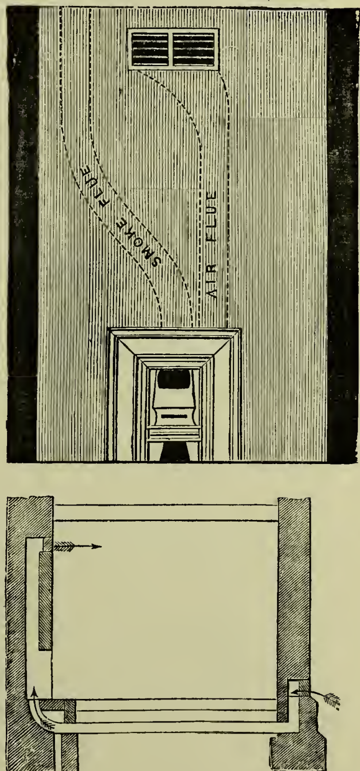


FIG. 20.—Elevation of Sir Douglas Galton's Grate, and Section of Room, showing Air-duct and Flues.

by means of an inlet flue from the outside, and, after being warmed, is passed into the room near the ceiling by the opening shown in the illustration. These stoves, known as Galton's ventilating stoves, are in general use in the British army for warming and ventilating barrack-rooms and hospital wards.

The chief objection to the use of hot air as a general means

of warming a room or dwelling lies in the fact that heated air is often unpleasantly dry, and when so employed should be moistened, or, if need be, purified by either filtration or washing.

Steam or **Hot Water** is closely allied to hot air for warming purposes. The ease with which all parts of a building can be heated by pipes containing steam or hot water is obvious, and, as applied to the needs of hotels, hospitals, churches, etc., is practically supplanting all other methods of warming. In the present day, steam is very little used for this purpose, since water, at either high or low pressure, is so much more convenient and cheaper. In a low-pressure water system the pipes are about 4 inches in diameter, and are always in a double row to allow of the water circulating. The boiler in connection with it is commonly placed in the basement of the building, and from its upper part runs a main pipe, ending in branches, which extend to the furthest end of the building; these then return underneath the others, unite into another single pipe, and then re-enter the boiler at its bottom. The circulation of the water is dependent upon the water, after being heated, being lighter than when cold, and as such tending to rise to a higher level; this having given up its heat to the various rooms, returns cooled by the lower pipe. The heat of the pipes is controlled by a valve which can be opened and closed at will. A feed-pipe from a supply cistern enters the return pipe near the boiler, while an escape for air is provided at the highest point of the system. In the high-pressure system, such as Perkins's, water is heated to about 300° F., in a portion of the pipes which pass through the kitchen fire. This system secures a greater heat, but requires very careful management, as any failure in the circulation would at once result in an explosion. Under the low-pressure system, 5 feet of a 4-inch pipe will warm 1000 cubic feet of air to 55°, and 12 feet will warm the same to 65°; but under the high-pressure, in which the heating power is something like two-thirds more, a proportionately less length of piping is required.

The Practical Examination of Air and Ventilation.

It has already been pointed out that the simplest test as to whether the ventilation of a room or a house is sufficient or not, is that of entering it from the external air, and noting the difference between the indoor air and the outside atmosphere in point of freshness. This test, however, only gives approximate results, and, in cases where more exactness is required, a more detailed examination is necessary. This, in every case, may be conveniently made to include the following points :—

1. The actual amount of cubic space, the relative size and position of inlets and outlets, and the amount of fresh air supplied.

2. The chemical examination of the contained air for impurities.

3. The nature of the suspended impurities.

4. Facts concerning the temperature and moistness of the air.

The determination of the actual amount of cubic space is merely a simple matter of measuring and calculation, combined with the making of certain deductions for bedding, furniture, etc., and irregularities in the shape of the space to be examined or additions for the cubic contents of open recesses. For each bedstead and bedding a general allowance of 10 feet is made, and for the body of each adult 3 cubic feet. If the room be rectangular or regular in shape, its cubical contents will be obtained by multiplying together the three dimensions of height, length, and breadth; if the space be irregular in shape, with either rectilinear or curved lines, it is usually most convenient to divide it up into simple parts, such as either triangles or circles, as the case may be, and calculate the cubical contents by one or more of the following rules. It is generally more convenient, too, to make the measurements in feet and decimals of a foot, than in feet and inches. If square inches are used, they may be turned into square feet by multiplying by 0·007.

Area of a circle = square of the circumference × 0·0796 or square of the diameter × 0·7854.

Circumference of a circle = diameter × 3·1416.

Diameter of a circle = circumference × 0·3183.

Area of an ellipse = the product of the long and short diameters multiplied by 0·7854.

Area of a square = the square of one of the sides.

Area of a rectangle = the product of two adjacent sides.

Area of a triangle = height × $\frac{1}{2}$ base, or base × $\frac{1}{2}$ height.

Area of any figure bounded by straight lines = divide it into triangles and take the sum of their areas.

Area of the segment of a circle = $(\frac{2}{3} \times \text{chord} \times \text{height}) + \frac{\text{cube of height}}{2 \times \text{chord}}$.

Cubic capacity of a solid triangle = area of triangle × height.

Cubic capacity of a cylinder = area of base × height.

Cubic capacity of a cone or pyramid = area of base × $\frac{1}{3}$ height.

Cubic capacity of a dome = area of base × $\frac{2}{3}$ height.

Cubic capacity of a sphere = cube of diameter × 0·5236.

Thus, supposing it were required to determine the cubic

capacity of a room 10 feet in height, and whose floor and ceiling shape were as drawn in the Fig., A B G C D. By dividing it into triangles and the segment of a circle, and then measuring the length of the various dotted lines, its total cubical capacity would

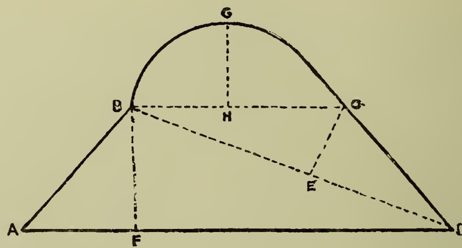


FIG. 21.

readily be obtained. Assuming A B to be 6 feet, B C to be 8 feet, C D to be 6 feet, B D to be 10 feet, B E to be 7 feet, E D to be 3 feet, F D to be 9 feet, F A to be 4 feet, E C to be 4 feet, G H to be 3 feet, and B F to be 5 feet, we get the cubical capacity of each of the figures to be as follows :—

		Cubic feet.
ABF	$4 \times \frac{5}{2} \times 10$	$= 100$
FBD	$9 \times \frac{5}{2} \times 10$	$= 225$
BEC	$7 \times \frac{4}{2} \times 10$	$= 140$
CED	$3 \times \frac{4}{2} \times 10$	$= 60$
BGC	$(\frac{2}{3} \times 8 \times 3) + \frac{27}{2 \times 8} \times 10$	$= 177$
This gives a total cubic capacity of . .		702

Having determined the total number of cubic feet, with all deductions and additions, and dividing this sum by the number of persons living in the room, the result is the cubic space per head; whilst the total area of the floor-space divided by the number of persons, gives the floor-space per head; this we know should be as near as possible $\frac{1}{12}$ of the cubic space. When this has been done, the next thing is to count the various openings in the room, and note the direction of movement of the air through them. As a general rule, one half of the openings will be inlets and the other half outlets, but this is not always so; the actual condition of affairs will be best learnt by observing the directions given to smoke disengaged by smouldering brown paper, velvet, feathers or even light balloons. The direction of the air-currents being known, their rate of movement must be determined either by an anemometer, if such be available, or by calculation of the theoretical velocity as obtained by Montgolfier's

formula, allowance being made, of course, for friction. If the ventilation is meant to be effectual when doors and windows are shut, these should be closed during this examination.

It may be accepted as a good rule that the amount of air issuing up a chimney or other large outlet is a far more reliable index of the fresh air being supplied than the amount actually ascertained to be entering through inlets; in fact, the fresh air supply can be rarely fairly estimated in any other way, as the air, even in the best of built houses, enters through many chinks and crevices or even through porous walls themselves, in such a way as to be beyond all absolute or accurate calculations.

Having, then, made these various preliminary inquiries, it may be necessary to chemically examine the respired air itself, in which case samples of the air must be taken at such times as will yield fair evidence as to the efficiency or not of ventilation. Thus, in the case of a bedroom, the sample yielded during daytime, with no one in the room, would be no value as an index of the state of the air during the night, when its usual occupants were sleeping in it. Therefore all samples should be collected at an hour when the greatest accumulation of impurities is likely to occur. For sleeping rooms this will usually be best secured at any hour between midnight and 5 a.m.

For the collection of an air sample, the simplest method is to obtain a glass jar or vessel, provided if possible with an india-rubber cap or stopper and capable of holding from half to one gallon, and then accurately measure its capacity. If this be filled with clean water, and, after emptying it in the room or air-space it is desired to examine, the jar be then carefully closed with either an indiarubber cap or stopper, the contents of the vessel will be so much of the air required to be examined. Since the amount of hurtful organic impurity in air increases or diminishes with the quantity of carbonic acid given off by persons inhabiting any particular air-space, the estimation of this gas constitutes the chief chemical examination required for ventilating purposes. For its determination the following method, known as Pettenkofer's, is at once the most simple and the most useful.

Estimation of Carbonic Acid in Air.—Having filled a Winchester quart bottle, or other suitable vessel of known capacity, with clean water and emptied it in that part of the air-space it is desired to examine, taking care to let it drain well, pour into it 60 c.c. of freshly prepared lime-water, and close it with an indiarubber cap or stopper. Shake the air and the lime-water in the bottle well up together, and allow to stand for half an hour or so. During this time the carbonic acid in the air within the bottle will be absorbed by the lime-water, and its causticity or

alkalinity proportionately lessened. The loss of strength, there fore, of the lime-water will be an index of the amount of carbonic acid present; but the strength of the lime-water must be previously determined, and this is usually done by means of a solution of oxalic acid, consisting of 2·25 grms. of oxalic acid dissolved in 1 litre or 1000 c.c. of distilled water, and of which 1 c.c. consequently exactly neutralizes 1 mgm. of lime, forming oxalate of lime. The exact point of neutralization can be determined by turmeric paper. If the strength of 30 c.c. of the fresh lime-water be tested, it will generally be found to be between 30 and 40 mgms. of lime. If, now, the strength of 30 c.c. of the lime-water which has been kept in the bottle of air for awhile be examined, it will be found to be much less, and the difference or loss of alkalinity represents the number of milligrammes of lime which have combined with the carbonic acid of the air in the bottle.

The milligrammes, however, of lime, need to be converted into terms of carbon dioxide, by calculation of the proportion between their molecular weights, which is as 56 is to 44, and then the CO_2 converted from milligrammes or measures of weight into cubic centimetres or measures of volume, which have a ratio one to the other as 1·9767 is to 1.

Suppose, in a jar of a capacity of 4385 c.c., it is found that 30 c.c. of lime-water, after standing some while, lose alkalinity, represented by 6 c.c. of the oxalic acid solution, equivalent to 6 mgms. of lime (CaO), then for the 60 c.c. of lime-water put in the jar the alkalinity lost is equal to 12 mgms. of lime. Since lime is to carbonic acid as 56 is to 44, therefore 12 mgms. of lime equal 9·4 mgms. of CO_2. But milligrammes of CO_2 are to cubic centimetres of CO_2 as 1·9767 is to 1, therefore 9·4 mgms. CO_2 equal 4·75 c.c. of CO_2. Now, the original capacity of the jar was 4385 c.c., and, deducting 60 c.c. for the lime-water put in, we get the jar to hold 4325 c.c. net of air in which we have found 4·75 c.c. of CO_2, which is in amount equal to 1·09 c.c. of carbonic acid in 1000 c.c. of air.

If the air of the room be above or below 32° F., a correction must be made by adding or deducting, as the case may be, 2 per 1000, or 0·002 for each volume. The reason of this correction being required is because the ratio between weight and volume of CO_2 as given above is only true for the precise temperature of 32° F., and consequently the volume of air must be corrected for just so much as the heat of the air varies from that temperature. Suppose the temperature of the room, when the sample of air was collected, had been 55° F., that is, 23° above the standard of 32°, therefore $23 \times 2 = 46$ per 1000 of CO_2 must

be added to what has been shown above, simply because there was that amount less of air in the jar at that particular temperature than there would have been had the temperature at the time of collection been at 32°; the result of this correction means that instead of 1·09 parts of CO_2 per 1000 of air being present, the true amount is 1·14 per 1000, or as 1000 : 1046 : : 1·09 : x = 1·14.

A further correction for barometric pressure may be made, if the height of the place is much above sea-level, or if the barometer read below the standard level of 29·92 inches; the correction being 0·26 per cent. for each difference of $\frac{1}{10}$ of a degree in pressure. As a rule, however, this correction is very rarely required.

The following simple process, proposed by Dr. Angus Smith, for the estimation of CO_2 in air is worthy of notice, particularly for those who cannot employ Pettenkofer's process. The method is based on the fact that a certain amount of carbonic acid is necessary to cause a given volume of lime-water to become turbid; or, in other words, that half an ounce of perfectly clear lime-water, when shaken with the air contained in a 20·63-oz. bottle, does not give a turbidity with air in which there is only 0·3 per 1000 of CO_2, but will do so if 0·4 be present. Similarly, if the same half ounce of lime-water be put in a 10·5-oz. bottle, it will not give a turbidity unless the ratio of CO_2 exceed 0·6 per 1000. Reference to the following table will give the results of various other sized bottles when using half an ounce of lime-water containing 0·0195 grm. of lime, and when the point of observation is "no precipitate" or turbidity.

Carbonic acid in the air per cent.	Volume of air in cubic centimetres.	Size of bottle in cubic centimetres.	Size of bottle in ounces avoirdupois.
0·03	571	584	20·63
0·04	428	443	15·60
0·05	342	356	12·58
0·06	285	299	10·57
0·07	245	259	9·13
0·08	214	228	8·05
0·09	190	204	7·21
0·10	171	185	6·54
0·11	156	170	6·00
0·12	143	157	5·53
0·13	132	146	5·15
0·14	123	137	4·82
0·15	114	128	4·53
0·20	86	100	3·52
0·25	69	83	2·92
0·30	57	71	2·51

Columns 1 and 2 give the ratio of carbonic acid in the quantity of air which will produce no precipitate in half an ounce of lime-water; column 3 is the same as column 2, with the addition of half an ounce, or 14·16 c.c., to give the corresponding size of bottle. The remaining column explains itself. It will thus be seen that different sized bottles containing half an ounce of lime-water will indicate approximately the ratio of carbonic acid in the air contained in them, by giving no turbidity when the bottle is well shaken. Thus if one of 8 ozs. is used, and there is no precipitate, it will indicate that the ratio does not exceed 0·08, and so on. Dr. Smith recommended that white glass-stoppered bottles be used, and that the lime-water be delivered into the bottle as quickly as possible, and that the air to be examined be made to enter by inhaling the air contained in it through a glass or caoutchouc tube, care being taken not to breathe into the bottle.

Estimation of Organic Impurities in Air.—Besides the estimation of carbonic acid, the chemical examination of air, strictly speaking, includes the determination of the organic matter and the ammonia in it. To obtain a merely approximate idea of the organic impurities, the air may be washed or drawn through a very dilute solution of permanganate of potash, of a known strength, and the result expressed as so many cubic feet of the air which it takes to decolourize 1 mgm. of the permanganate. The estimation of the ammonia in air is a still more delicate process, and is performed by washing the air with ammonia free water and then estimating in the water the ammonia yielded by the air; the actual process is described in the following chapter on water. As tests for the determination of various degrees of respiratory impurity, both the estimation of the organic matter capable of being oxidized by permanganate and of the ammonia present, are quite subsidiary to that for determining the carbonic acid, and but rarely employed.

Examination of the Suspended Matters in Air.—This will, of course, be essentially microscopic. The suspended matters contained in the air of any particular space or locality may be conveniently collected by drawing the air through distilled water, then, after allowing the suspended matters to subside, to examine them under the microscope; or the air may be drawn or sucked into an exhausted receiver, through a fine aperture, so as to strike upon a piece of glass moistened with glycerine, which, of course, arrests the suspended matters. This is practically the plan of Pouchet's æroscope. Another plan is to aspirate the air through a filter of very finely powdered sugar; this is then dissolved by water, leaving the suspended matter of the air, which had been, as

it were, caught, available for examination. As an alternative to these plans, one may take a bent glass tube and sterilize it by making it red hot in a flame; after this, immerse it in a freezing mixture of ice and salt, and slowly aspirate air through it. The moisture of the air drawn through is condensed inside the tube, sinks to the lowest point of the bend, having entangled all suspended matters with it. These can be readily transferred to a slide, and examined under the microscope.

These methods are not sufficiently exact to secure bacteria, moulds, or any of the smaller micro-organisms. Various instruments have been proposed to enumerate and examine the more minute micro-organisms in the air; but, on the whole, the work in this direction has been imperfectly successful. Perhaps the best method is that with Hesse's instrument. He aspirates air slowly through a wide horizontal glass tube, the interior of which, after careful sterilization by heat and washing with alcohol, is smeared or coated with nutrient gelatine. The air enters through a hole at one end, and at such a slow speed as to allow all the suspended particles to fall upon the gelatine before reaching the other end. On being placed in favourable conditions, the various micro-organisms grow upon the gelatine, and can be subsequently examined as to their precise nature. As a rule, the bacteria are much less plentiful than the moulds and fungi, but in air which has been rendered impure by either respiration or by other effluvia, the exact reverse is found to be the case.

In carrying out all inquiries as to ventilation, the various facts connected with the temperature and moisture of the air need to be ascertained. These observations will be best made by means of thermometers to measure the heat, and by hygrometers to estimate the amount of moisture present. Details regarding the nature and use of these instruments will be more conveniently given in a subsequent chapter upon meteorology and meteorological instruments.

In a room, well ventilated and warmed, the temperature should not fall below 60° F., the moisture or humidity ought to range between 72 and 77 per cent., while the carbonic acid, as previously stated, should not exceed 0·6 parts per 1000 volumes of air.

CHAPTER II.

WATER.

Water is found widely diffused in Nature, and enters into the structure of plants and animals as well as nearly every tissue of our bodies. As a solid, we meet with it in the form of snow and ice; as a liquid, in the sea, in streams, rivers, and lakes; while, as vapour, it forms one of the constituents of the atmosphere, and of the breath which we exhale from our lungs. It is by means of the water we take in with our food that the solid portions of it are changed and dissolved, and its nutrient principles enabled to enter into the blood, to enrich it and thereby build up the body tissues. The supply of water is therefore a fundamental necessity, and health depends greatly upon a supply of it, sufficient in quantity and pure in quality.

Water is a chemical compound, consisting of two atoms of hydrogen with one of oxygen, and is formed whenever hydrogen gas or a combustible substance containing hydrogen is burnt in oxygen or atmospheric air. In its purest state it is free from taste and smell, and, between 32° and 212° F., under ordinary atmospheric pressure, is a transparent and almost colourless liquid.

In its liquid state, water is about 770 times more dense than ordinary air, this density being actually at its maximum at 39·2° F. or 4° C. The density of water is always taken as the standard of comparison in reference to the densities of other liquids or solids. In this country the density of water at a temperature of 60° F. is usually taken as unity, but on the Continent the temperature of its maximum density is more usually adopted, namely 39·2° F. or 4° C. Some idea of the weights of certain volumes of water, in terms of both our own system of weights and measures and that of the metric system as used on the Continent, will be gathered from the table at the top of p. 61.

Water possesses a certain amount of elasticity and compressibility. Thus, by increasing the pressure by the weight of 200 atmospheres to which water is exposed, its volume is said to be reduced $\frac{1}{12}$ in. This compressibility of water increases as the temperature rises. Water has a high capacity for heat, but yet it is a very bad conductor of heat. When water is heated from below, the heated portions of it expand, and thus, becoming specifically lighter, tend to rise to the surface, while the colder and denser parts of it sink until they, in their turn, being heated the whole mass acquires a uniform temperature.

Grains.	Cubic centimetres at 4° cent. as grammes.	Cubic inches at 60° F.	Pounds.	Gallons at 60° F.	Cubic feet at 60° F.
1					
15·432	1	0·061		0·0002201	0·0000353
252·456	16·386	1			
7000	454·345	27·727	1	0·1	0·016046
70000	4543·458	277·276	10	1	0·16046
436495	28315	1728	62·355	6·2355	1

At a temperature of 32° F. or 0° C. water becomes solid or freezes, and at the same time expands nearly one-eleventh of its volume, a fact which explains the reason why, during frosts, frozen pipes burst or split, and why damp soils or rocks containing moisture tend to crack during frost. This solid water or ice has a less density than liquid water, consequently ice always floats on the surface of the water, and, since the density of water is greatest at 39·2° F., or a few degrees above that of freezing, it consequently follows that such portions of it which are cooled below that point or freeze remain at the surface, while the water just below remains a few degrees warmer.

As already explained in the chapter on air, water evaporates from its surface at all temperatures, and its vapour thus formed has a density and tension determined by the temperature. Under the ordinary pressure of the atmosphere, which has also been explained as being equal to 29·92 inches of mercury, water boils at a temperature of 212° F. or 100° C., and is converted into more than 1600 times its own volume of vapour. If the pressure be reduced to nearly that of a vacuum, the boiling point of water is nearly that of 32° F. or 0° C.; but if the pressure be increased, then the temperature of the boiling point is raised, as shown in the following table:—

Pressure, in atmospheres.	Temperature of Boiling Point.	Pressure, in atmospheres.	Temperature of Boiling Point.
	F.		F.
1	212°	8	341·7°
2	250·5°	10	358·8°
3	275·7°	20	418·4°
4	293·7°	25	439·3°
5	307·6°	30	457·1°
6	320·3°	35	472·6°
7	331·7°	40	510·6°

The boiling point of water under the ordinary pressure of the air is slightly influenced by the nature of the vessel in which it is heated, and by the smoothness or roughness of its surface. Thus in smooth vessels, like those of glass or porcelain, water boils at a higher temperature than in those with a rough surface, like iron. Water has a remarkable power of dissolving substances, and there are but a few substances which water cannot to some extent dissolve. Generally the solubility of solid or liquid substances is increased in proportion as the temperature is raised, but there are exceptions to this rule: in the case of gases, the amount which water can dissolve is largely dependent upon pressure: and under ordinary pressure it is generally larger in proportion as the temperature is lower. The watery solution of solid substances and of certain liquids and gases have a higher density than ordinary water, but, as a rule, the density of watery solutions of liquids and gases is less than that of water. The freezing point of water solutions is lower than that of water, thus sea water, which is largely a solution of various salts of magnesium, sodium, and potassium, freezes less readily than fresh water. The boiling point of water is raised when it contains solid substances in solution, and this to an extent largely proportionate to the amount of substances in solution.

Quantity of Water required.—The amount of water used varies very much in different communities, being dependent on the conditions of the place and population. In London, the Public Water Companies deliver 29½ gallons per head daily. Edinburgh uses 40 gallons, Dublin 35 gallons, Glasgow 50 gallons, Berlin 15½ gallons, Vienna 22 gallons.

Water is required for drinking and cooking purposes, for personal ablution, for the washing of clothes, utensils, and houses, for the cleansing of closets, and for flushing drains and sewers; these amounts are generally included under domestic supplies. In towns, streets have to be watered, horses and cattle supplied, provision made for extinguishing fires—public fountains and trade purposes generally provided for. Roughly about ten gallons per head a day are required for domestic purposes, and about as much more for flushing drains and sewers—making twenty gallons; the average for trade and public supplies in towns may be taken at an additional ten gallons. The table on p. 63 gives in detail the approximate quantities usually allowed.

An adult man will drink from 50 to 60 ounces daily, exclusive of the amount of water contained in his so-called solid food; but the quantity varies, depending upon the season of the year and the occupation of the individual. Women and children

drink less water than men. With a constant supply in towns there is no doubt considerable waste, and by due economy a smaller quantity would suffice.

	Gallons daily for one Person.
Cooking	0·75
For drinking	0·33
Baths	5·0
Share of house washing	3·0
Share of laundry washing	3·0
If a general bath add	4·0
Water-closets	6·0
Unavoidable waste	3·0
Total	25·0
For town purposes, etc.	5·0
Add for manufacturing towns	5·0
	35·0

The amount required for animals varies, and depends, as in the case of men, on the food, season, and exertion. During hot weather, horses need more water than with a cold season. The following quantities approximate as closely as possible to the amount required :—

	Gallons.
Large oxen	6
Small oxen	5
Horses	6
Mules and ponies	5
Sheep or pig	1

In the army, eight gallons is allowed daily for each cavalry horse, and ten gallons for an artillery horse; but the latter includes the washing of the carriages.

In hospitals a very much larger supply is required, and generally the amount used is double the ordinary supply, the average being from 60 to 70 gallons per head daily. The London Hospital uses 62 gallons; St. Thomas's Hospital, 99 gallons; the Royal Victoria Hospital, at Netley, 63 gallons; the Cambridge Hospital, at Aldershot, 90 gallons; the Herbert Hospital, Woolwich, 89 gallons.

Rain Water.—All natural water is derived from the rainfall. From the surface of the sea and from the land, water rises, under the influence of the sun's rays, in the form of invisible vapour; it forms clouds by being separated from the air, and descends under changes of temperature in the form of rain, dew, mist, snow, sleet, and hail. Part of this water is again evaporated, part flows off in the form of streams and rivers, while part sinks in through cracks and fissures into the earth until it reaches an impermeable stratum, when it forms the

ground water, and flows beneath the surface of the ground at varying levels towards the sea or nearest water-channel, or finds its way to the surface in the form of springs.

Rain water, if collected in clean vessels as it falls in the open country, is usually very pure and wholesome. Near the sea it may contain chlorides and sulphates, due to its sea origin. It is soft, owing to the absence of the salts of lime and magnesia.

As rain descends through the air it washes it, taking up oxygen, nitrogen, and nitrates, and any suspended matters which may be present in the air, so that before it reaches any collecting surface it may have added to it as much as two grains of solid matters in a gallon of water. In inland districts, especially where large manufacturing works are carried on, these impurities may be increased by the additions of sulphurous and sulphuric acids and ammonia, and generally with the products of coal combustion, which may be either suspended or dissolved in the air.

Rain water is very frequently contaminated by impurities taken up from the surfaces on which it falls, such impurities generally consist of bird-droppings, decaying leaves, soot, and such matters as collect on the roofs of buildings; if the water is acid it will dissolve lead from the gutters, or zinc, should that metal be present or the water collected from galvanized iron buildings. In order to prevent the suspended matters passing into the storage tank, a rain water-separator is sometimes used. This allows the roof to be washed by the first rainfall, and that portion of the water is rejected. When the roof has been washed, it cants and stores the rain water. The separator acts automatically (Fig. 22). The average rainfall for the last two decennial periods in the United Kingdom is given in the following table:—

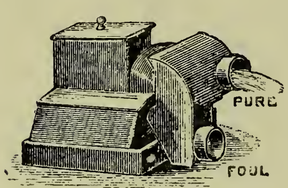


FIG. 22.—Rain Water Separator.

Rainfall.	1870–79.	1880–89.
England and Wales	35·56	33·76
Scotland	40·43	46·56
Ireland	35·86	38·54
Average of the United Kingdom	36·50	37·30
,, Great Britain . . .	36·52	36·69

The rainfall varies in different districts. On the east coast of England it is about 20 inches; on the south coast 30 inches;

and on the west coast about 70 inches. As a general rule, those districts which have a low rainfall receive the greater part of it during the summer months, while those in which the rainfall is much above the average, the amount of winter rain is greater than that which falls during the summer.

The quantity of water which can be utilized from the rainfall may be calculated if the amount of the rainfall and the area of the receiving surface is known. It is necessary to know not only the average quantity which falls in any district, but also the amount which falls in the wettest and driest year. As a general rule, the rainfall in the driest year is one-third less than the mean fall in the wettest year, and the wettest year one-third greater than the mean fall. The average of the three driest years is a safe basis on which to calculate the supply.

A simple method for calculating the amount of water given by rain is to multiply the area of the receiving surface by half the rainfall in inches, the result is in gallons; the error here is only about 4 per cent. On an average six-tenths of the rainfall is available for storage. One inch of rain delivers 101 tons by weight, or 22·617 gallons on each square acre. If the inches of rainfall be multiplied by $14\frac{1}{2}$, the result equals the millions of gallons per square mile.

Springs and Rivers.—Rain, flowing over and through the land, supplies springs and rivers. The amount which flows off the surface in streams or which penetrates into the ground depends on the configuration of the surface, the nature of the soil, the season and temperature, and to a lesser extent, on the movement of the air. In summer, owing to an increase of temperature, evaporation is rapid, and less water penetrates the surface or runs off in the direction of the natural watercourses than in winter; the ground is drier, and more readily absorbs moisture. Evaporation is 50 per cent. less on a flat district than on an undulating rocky country. In a clay district hardly any water will sink into the ground, while a very large amount infiltrates into a loose sand or gravel soil. In the magnesium limestone districts about 20 per cent. of the rainfall penetrates into the ground; in the new red sandstone 25 per cent.; in the chalk 42 per cent.; and in loose sands 96 per cent.

Penetrating into the ground, rainfall absorbs carbonic acid from the air as it passes through the interstices of the soil, which is nearly 250 times richer in this gas than the air above it; aided by this and by the temperature of the soil and pressure, it dissolves from the soil lime, and everything else that it meets with which can be taken up in the time from the strata through which it passes.

It also takes up organic matter from the soil, more especially

when it falls on cultivated lands and inhabited areas, but Nature's processes in the soil tend by oxidation to render these products harmless unless they are excessive.

Springs are the outcrop or overflow of the ground water. The rain which falls on a permeable stratum percolates downward until

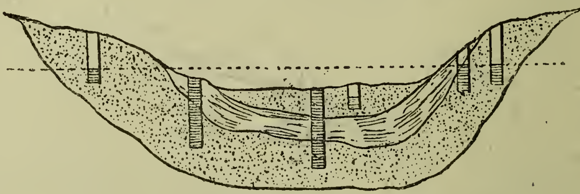


FIG. 23.—Diagram showing the tapping of the ground water above and below an impermeable stratum.

it is arrested by a bed of clay or other impermeable stratum, and this rain water which is stored underground crops up to form springs.

When these appear flowing from artificial beds of gravel they

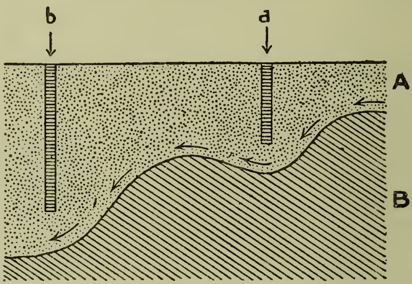


FIG. 24.—Diagram showing flow of the ground water, A being a permeable and B an impermeable stratum.

are called "land" springs: when, however, they are found in the deeper strata they are termed "main" springs: the former are shallow and uncertain and their flow cannot be depended on, while the latter yield a somewhat regular and constant supply.

River water is derived partly from springs, but its chief source is from that part of the rainfall which flows off from the surface of the ground.

If the supply is taken from the head waters or source of the river before impurities can gain access to the water, it is generally pure and the water has all the characters of an upland surface water. Unfortunately, most rivers are subject to pollution in their course either from drainage from cultivated lands or from the sewage of villages on their banks being permitted to pass into them.

The organic matter which thus gains access is to some extent

oxidized and rendered innocuous in those rivers in which the current is rapid and where the water in its flow is broken up by rocks and boulders and exposed to the action of the air; the presence also of aquatic and bacterial life assist in its purification: but even then this is no safeguard when sewage is permitted to foul the water. Rivers or streams are sometimes dammed up so as to form an impounding reservoir, as in the case of the Vyrnvy, supplying Liverpool, and the Vartry at Dublin. These waters afford good supplies provided the gathering grounds are efficiently protected.

Wells are either shallow wells or deep wells. A well of 50 feet in depth or less is generally regarded as a shallow well: one of 100 feet or more, as a deep well. Shallow wells draw their supply from the subsoil water, while deep wells tap the water-bearing stratum beneath the impervious stratum: the latter are sometimes of great depth, and are called Artesian wells, having been first sunk in the province of Artois, in France. The water from these wells is generally pure, but it is not unusual to find in it a large amount of chloride of sodium and a good deal of free ammonia; it is generally poor in oxygen, not well aerated, but is moderately palatable. Deep-well waters are much harder than other classes of water, for they dissolve out much lime, magnesia, and the alkaline salts in their long course underneath the surface of the ground.

Wells furnish water supplies to most rural districts, and their depth generally depends upon the nature of the soil and on the height of the underlying ground water. Shallow wells may yield good water provided there is no risk to pollution from surface washings or from their proximity to drains and cesspools, but in every case it is wise to go deep enough to place an impervious stratum between the water supply and the surface of the ground, and thus to effectually shut off surface impurities from entering and fouling the water in the well. If this cannot be done, the well should be sunk as deep as possible into the water-bearing stratum, and protected by steining with brick and cement, this being carried sufficiently high above ground to prevent surface washings from entering the well.

The distance drained by wells is undetermined: it has been given as a circle, the radius of which is the depth of the well, but there are good grounds for believing that much larger areas are affected, and that the flow of water has been influenced at a distance many times the radius; the pressure of tidal rivers has been known to influence the wells at Budapesth at a distance of 2700 feet. Wells are largely influenced by the nature of the soil, by the movement and direction of the ground water, and by the amount of water drawn from them. A porous soil with no impervious superficial stratum will admit of impurities reaching

the well from the surface which a clay soil would shut off. The

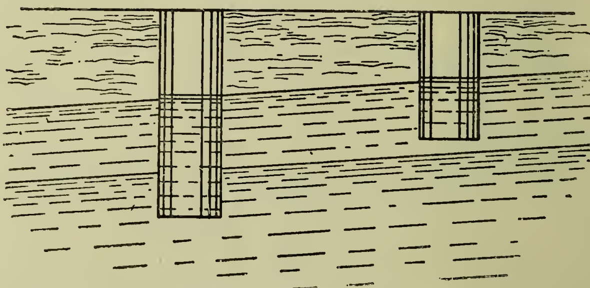


FIG. 25.—Diagram showing how a sudden rise in ground water may lead to communication between cesspool and well, previously disconnected.

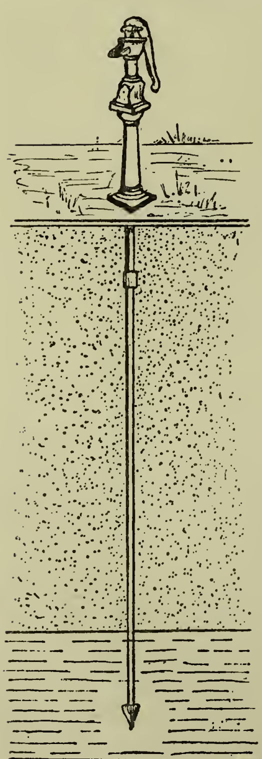


FIG. 26.—Tube well.

movement and direction of the ground water being in the direction of the nearest water-course or the sea, to protect the water supply from any soakage from leaky cesspools or other sources of pollution, the well should be placed above them, to windward, as it were, of all such possible sources of contamination.

A well which yields a moderate quantity of good water may, if the demand on it be increased, draw in water from the surrounding parts to meet the supply, and thus tap sources of impurity which a moderate demand left untouched. A sudden rise in the ground water may also lead to direct communication between a cesspool and a well, by the water tapping the former in its flow.

Tube wells, commonly known as Norton's Abyssinian tube wells, are used when a temporary supply is required: they are superior to dug wells, which, from imperfect steining or total absence of it, are liable to become foul from surface pollution. They are constructed by driving tubes into the soil, one length being screwed on to another, the first tube being perforated at the bottom for about two feet, its lower end being furnished with a steel point (Fig. 26). When the subsoil water is reached, a pump is attached to the

tube; the water after pumping a short time is clear; the tube forms a cavity which corresponds to the ordinary well at the end of the pipe, owing to the removal of the soil by pumping. Dr. Koch recommends that iron tubes be placed in dug wells, and the surrounding space filled in with clean gravel and sand, the water to be raised by a pump fixed at the surface.

Collection and Storage.—When water is required for towns it is generally collected in reservoirs and distributed by gravitation. The size of the reservoir will depend on the quantity of water used, and the means of refilling it; when the yield is subject to intermissions, large storage capacity becomes necessary.

The capacity for a reservoir may be calculated from the following formula:—

$$D = \frac{1000}{\sqrt{f}}$$

where f = mean annual rainfall in inches of three consecutive years, say $\frac{5}{6}$ of the average annual rainfall, and D = number of days' supply to be stored. For example, with an average rainfall of 25 inches, we have—

$$\frac{1000}{\sqrt{25}} = \frac{1000}{5} = 200 \text{ days' supply.}$$

Reservoirs are placed on as high ground as possible, to give a sufficient head or pressure of water, so that every part of the district may be supplied by gravitation; from thence the water is distributed by cast-iron pipes. Service reservoirs should be covered and ventilated, and the water from the supply reservoir carefully filtered through filter beds of sand before it is permitted to enter the service reservoir for distribution. In form they should be deep rather than extended, as this lessens evaporation and secures coolness. In case of ground supplies obtained from wells or springs, the water is generally free from organic growths, and in storing it in service reservoirs it is only necessary that no opportunity should be given for the growth of organisms. If the supply is taken from surface water there is already organic growth present, and the water has to be freed from this by filtration, so as to convert it into a ground water, and then in both cases to protect it from the action of light; it is now recognized that the growth of fungi in water, stored in reservoirs, can be prevented by the exclusion of light.

If the reservoir is so large that it cannot be covered in, a second or service reservoir, capable of holding a few days' supply, should be provided, into which, after filtration, the water from the supply reservoir might be lead as required.

Distribution.—Water collected as thus described may be

distributed on the *constant* system, in which the supply pipes are always kept full of water, or on the *intermittent* system, in which the water is only turned on at intervals for a short time during the day. The constant supply is the one usually aimed at, as no cisterns are required for storage, and the drinking water is taken direct from the main. When the supply is intermittent it is necessary to have cisterns in which to store a sufficient supply of water during the intervals that the water in the mains is turned off; the mains are also liable to be fouled by impurities in the soil, such as gas from leaky pipes lying in their vicinity; the foul air, aided by the suction action of the pipe when the water is turned off, enters through the joints, which are not infrequently caulked with tow and gaskin, and are not impervious.

Water is usually distributed by iron pipes laid some distance underground, the thickness of the pipe being dependent on the pressure to which it is subjected by the head of water. The lengths of pipes are put together by a spigot joint packed with lead. The practice of caulking with tow and gaskin and then running the joint with molten lead never secures a proper joint; the tow and hemp rot, and contaminate the water as well as causing waste from leakage. Cast-iron pipes, unless protected, rapidly corrode, especially if the water is soft. It is usual, therefore, to coat these pipes with a protective material before laying them down. Angus Smith's process is the one very generally adopted. A varnish distilled from coal tar until the naphtha is entirely removed is deodorized and a small quantity of linseed oil added; this mixture is carefully heated in a tank to about 300° F., when the pipes are immersed in it, and allowed to remain until they attain a temperature of 300° F. Some engineers prefer Barff's method, which consists in raising the temperature of the metal to about 1200° F.—a white heat—in a suitable chamber, into which is passed super-heated steam; the metal is exposed to this action for several hours, and becomes coated with a protective oxide; this plan is coming into very general use. Iron pipes last longer if kept constantly full of water, and are not so liable to corrode as those which are alternately full of air and water.

The disadvantage of the constant-supply system is the greater waste from leaky pipes, due to settling of the ground after laying, to fracture from pressure owing to heavy traffic, and the expense of the renewal of the fittings which must be of the best description; but in practice it has been found that with proper fittings there is no great loss. A plan has been recently introduced by Mr. Deacon by which any large waste occurring in any district may be at once detected. He has invented a water-waste meter,

or detector, which registers the flow of water both by day and by night. These are fitted to each district main, and as only a very limited quantity is used at night, any waste can be at once detected, since what passes through the metre must run to waste. The place where the leakage is can be localized by the vibrations produced in the nearest house pipes, and which are audible on applying the ear to the stand pipe. By this method leakage can be at once found out, and an enormous saving effected.

Service pipes communicating with houses are made of lead or galvanized iron; lead pipes should only be used when it has been proved that the water has no action on that metal. Soft waters are especially liable to act on lead, an oxide of lead being formed which is dissolved again; for such waters, composition pipe, made of an amalgam of lead and tin, has been used, and is said to answer. Iron pipes coated with vitreous glaze answer best, but on account of the difficulty in fixing them, and their cost, they have not come into general use. Galvanized iron pipes are now very generally used; they are not liable to rust, and stand the pressure of water well. Block-tin pipes are excellent, but very expensive: water does not act on them, and they last for a long time; their cost, however, is almost prohibitive against their coming into general use. Composite pipes, consisting of block tin enclosed in a lead pipe, are not liable to be acted on by water, but if the surface of the tin is fissured, either in fitting the pipe or by frost, galvanic action takes place, and the lead is rapidly dissolved; they are, however, said to answer where they have been used.

The action of water on iron pipes appears to diminish after their use for a short time. Barff's method has also been applied to service pipes, and appears successful; it is said, however, that the coating of protective oxide does not last, but soon wears off.

Cisterns are usually made of slate, stone, iron, galvanized iron or lead; the latter should never be used when the water supply is taken for drinking purposes. Slate is an excellent material, but is liable to leak at the joints; in no case should red lead be used to repair these cisterns. Stone-ware makes a good cistern, but its weight is against its use. Iron cisterns rust and discolour the water; they may, however, be protected by being lined with cement (Crease's patent). Galvanized iron cisterns are those most generally used; they have been known to give up zinc to water, but this is so exceptional that it should not prohibit their use. Cisterns should be so placed as to be easy of access and readily cleaned. If the water is exposed to frosts, the sides should be made to slope: this will prevent their fracture owing to

the expansive force of the water on freezing. The overflow or waste pipe should not communicate with any drain, but open free to the air above a grating sufficiently high to prevent foul air rising through it and contaminating the water. For the same reason the supply pipe of any water closet should not pass direct from the cistern, but a smaller cistern (water-waste preventor) should intervene.

To permit of cisterns being periodically cleaned, it is better to have two smaller cisterns than one large one, so that there may be no inconvenience in emptying the one or the other at any time. Cisterns should always be covered to protect them from dust, soot, and other contaminations, as dead mice, birds, etc.; they should also be ventilated and protected as far as possible from both heat and light. Tanks to hold rain water require even more constant care than cisterns, as the water carries impurities with it from the roofs of buildings from which it is generally collected.

With an intermittent supply, the cisterns in the smaller class of houses are not large enough to fulfil the requirements of the occupants, and stand-pipes are generally erected to supplement the supply; this is avoided where the constant service has been introduced, and the evils attendant with the storage of water is prevented. A great waste has often followed on the change from the intermittent to the constant service, mainly due to the fittings not being able to stand the greater strain placed on them; constant supervision is required to see that this is not a cause of waste. Screw-down taps should always be provided, and not a common stopcock, as there is less pressure on the pipe when the water is turned off slowly. The water drawn direct from the main is cooler, and, as a rule, better aerated than when stored in cisterns. Some water companies introduced a ferrule or throttle of very small diameter, so as to allow the water to pass extremely slowly from the taps, but the inconvenience and inutility of the practice has caused its discontinuance. A screwcock to turn off the water just as it enters the house is also necessary, so as to shut off the supply if needed; this is very essential during frost, and, if supplemented by a tap at the lowest part of the pipe so as to enable the water to be drawn off, there will be little danger of pipes bursting from this cause.

Pipes, if made of lead, should be sufficiently strong to stand the strain of high-pressure supplies; they are usually 9 lbs. per yard for one-inch pipes, and 21 lbs. per lineal yard for 2-inch pipes. In order to limit waste, many companies propose to deliver in special cases water by meter, but this would have the disadvantage, if applied to communities, of restricting the use of

water, which is not advisable. The advantages of the constant service in the case of fire is obvious.

Action of Water on Lead Pipes.—The waters which act most on lead are—

(*a*) The purest and most highly oxygenated, as distilled water, rain water, and generally soft waters from moorland districts and lakes.

(*b*) Those waters containing organic matter, nitrates, and nitrites.

(*c*) Waters containing an excess of chlorides.

(*d*) Those containing a free acid, such as humic, ulmic, and sulphuric.

The waters which act least on lead are—

(*a*) Hard waters: those containing carbonates have especially a protective influence, particularly carbonate of lime.

(*b*) The presence of free carbonic acid, provided this is not in excess, has a protective influence.

(*c*) The presence of silica in the water, an insoluble silicate of lead being formed.

But apart from the chemical character of the water, there are other conditions which add to this plumbo-solvent action; chief of these are—

(*a*) Temperature: hot-water pipes yield more lead than cold-water pipes.

(*b*) Pressure increases the solvent action.

(*c*) The length of time water has been in contact with the pipe, its action being most rapid during the first 24 hours.

(*d*) It has also been suggested that the presence of micro-organisms in water influences the plumbo-solvent action. Water rich in bacterial growth is said to act on lead, giving a seasonal character to this action.

(*e*) Galvanic action also aids solution of the metal, if this is set up by the juxtaposition of two metals. A water containing as much as $\frac{1}{10}$ of a grain in the gallon is unfit for drinking purposes, and even $\frac{1}{20}$ of a grain may be unsafe, as this amount has been known to affect some persons. Filtration removes lead from water, if the filters act properly.

Quality of Water Supplies.—Rain water, if properly collected and stored, affords an excellent supply in country districts. In towns it takes up such impurities from the air and from the various collecting surfaces on which it is gathered, that it cannot be looked upon as satisfactory. The uncertainty of the supply and the length of a dry season necessitates large storage capacity, which is not desirable. Rain water should be filtered to remove suspended matters before being stored, and the tanks protected from light and heat. The hygienic value of rivers, springs, and wells

as sources of supply depends on many details. Spring water may be both pure and impure; it is generally, however, free from organic impurity, while its mineral constituents are large. River water, on the contrary, is more liable to vegetable and animal contamination than springs are, while its mineral constituents are less. Shallow-well water should always be viewed with suspicion, by reason of the danger from surface pollution during heavy rainfalls.

Hard and Soft Waters.—Water is frequently described as *hard* and *soft.* Hardness is due to the presence in the water of the salts of lime and magnesia. If it is in the form of carbonates, and if its amount is not excessive, it renders water palatable, and does not interfere with its wholesomeness; but if, on the other hand, it is caused by the fixed lime and magnesia salts, it is objectionable. Hard waters are also wasteful, as in washing much soap is expended before a permanent lather is obtained. Vegetables boiled in such water tend to become hard, and are difficult to digest. The difficulty of infusing tea with such water is well known.

The following tables show the characteristics of water from different sources (*Rivers Pollution Commissioners' Report*) :—

1. In respect of wholesomeness, palatability and general fitness for drinking and cookery :—

Wholesome	1. Spring water	very palatable.
	2. Deep-well water	
	3. Upland service	moderately palatable.
Suspicious	4. Stored rain water	
	5. Surface water from cultivated lands	palatable.
Dangerous	6. River water, to which sewage gains access	
	7. Shallow well water	

2. Classified according to softness with regard to washing, etc.

1. Rain water.
2. Upland surface water.
3. Surface water from cultivated land.
4. Polluted well waters.
5. Spring water.
6. Deep-well water.
7. Shallow-well water.

3. As regards the influence of geological formation in rendering the water sparkling, colourless, palatable, and wholesome, the following water-bearing strata are the most efficient :—

1. Chalk.
2. Oolite.
3. Green sand.
4. Hastings sand.
5. New red sandstone.

The general characters of a pure and wholesome water are as follows. It should be clear, sparkling, showing that it is well aerated, free from colour and taste, and not too hard, so as to interfere with the cooking of vegetables, etc. There should be no sediment, and if any it should consist only of a little mineral matter. Where there is any marked deviation from this standard the cause of it should be carefully inquired into.

Impurities in Water.—The geological formation of a district influences the composition of the water which passes through it; while affording a valuable guide, it by no means tells with absolute certainty what the constituents of the water may be. The following soils generally yield a supply of pure water:—granite, metamorphic and clay slate soils, hard oolite and chalk. Water from these soils is usually very pure, containing a little lime and magnesia, carbonate and sulphate, but a very small amount of organic matter. Waters from the sands, sandstones and gravels vary greatly in composition, and are uncertain sources of supply; the green sand waters are usually good, and in clean gravels, if not situated near towns, the water is often free from impurities. Sometimes the sands contain large quantities of soluble salts, which are dissolved by the water; frequently, also, the organic matter is high. The limestone and magnesium limestone waters are usually free from organic impurity, but may contain the fixed hard salts—calcium sulphate and magnesium sulphate—in excess; they are not as desirable a source as the chalk waters.

The chalk waters are clear, sparkling, well aerated, being highly charged with carbonic acid; there is usually a very small amount of organic matter present, and, although hard, they can be very effectually softened; they are wholesome waters, as a class, and are pleasant to drink.

Surface and subsoil water are a common source of supply in country districts; these waters should always be regarded with suspicion, unless taken from places which are far removed from possible pollution. Marsh waters are soft and well adapted for washing purposes, but the vegetable organic matter is high, and there is usually much suspended matter present. In tropical countries, such waters are unfit for drinking purposes, as they may produce malarial fever in a severe form.

Artesian well-water varies; it frequently contains an excess

of sodium chloride and carbonate, and there is usually present free ammonia in considerable quantities; it is generally flat and insipid, and for this reason is not very palatable.

Wells situated near the sea-coast usually contain a large amount of saline mineral matter. In cases where this is excessive, surface wells and rainfall afford the only available sources.

Effects of drinking Impure Water.—Although it is a generally recognized fact that any large and sudden outbreak of epidemic disease in a community, especially if it is localized, is usually due to the pollution of the water supply, yet there are many instances on record where its use has been the cause of ill-health, without producing such marked effects. The diseases which are associated with the use of impure water are cholera, enteric fever and dysentery, dyspepsia and diarrhœa; malarial fever in tropical countries, goitre, parasitic diseases, and metallic poisoning. The virulence of an epidemic disease has some definite relation to the purity of the supply, for, once seeded with the specific poison, a polluted water appears to act more virulently than one that is pure. From our knowledge of the presence of infective organisms, it would appear doubtful whether they survive in good water for any lengthened period. Laboratory experiments show that from 14 to 21 days has been the maximum period of their vitality, and probably under any favourable conditions a much shorter period would complete their life.

Waters containing an excess of the fixed hard salts of lime and magnesia frequently cause diarrhœa and dyspeptic symptoms, especially among those who are unaccustomed to use them. Carbonate of lime does not appear to have any injurious effect, nor, on the contrary, is it essential, as it was formerly believed to be; if it is, it is best to have it in some other way than in drinking water. Diarrhœa has been caused by the suspended matters in water, which affect the intestinal tract by mechanical irritation. Waters to which sewage gains access produce diarrhœa in those who are not used to them, though long habitude in the use of such waters appears to induce a condition in which the system tolerates them. Goitre is a disease said to be caused by drinking water derived from limestone and dolomitic rocks; that goitre is prevalent in places where the water is very hard is undoubted; but it is also said to exist where the drinking water is soft, and contains very little of the sulphates of lime and magnesia; it has also been attributed to the presence of iron pyrites in the water. The question is one that has not been definitely settled; probably water is really only one factor in the causation of this disease.

That dysentery has been caused by impure water there is ample evidence to prove; in nearly every instance, the water was

polluted with fœcal, and probably with dysenteric discharges, and where the supply was discontinued, the disease disappeared; it may also be said that water contaminated with organic impurity acts as a predisposing cause by exercising an irritative action on the bowels, as well as being directly the vehicle by which the specific poison is introduced into the system.

Enteric fever is more often spread by impure water than by any other means. The disease is usually regarded as being associated with a specific poison, although some observers recognize that it may also have a *de novo* origin. It is, however, abundantly proved that specifically infected water does produce this disease, and that the subsequent dilution of the poison by an enormous quantity of water is no safeguard, once sewage infected with the germ gains access to the supply. Dr. Barry's report on the Tees water supply clearly showed that the incidence of the fever fell on those districts which drew their water supply from the Tees, while those who drew their supply from other districts escaped. In this epidemic, the attacks were spread over all the several districts — ten in number — supplied with this water, several districts being attacked simultaneously; while, apart from the water supply, there was no difference of any importance between those drinking the Tees water and the other districts which were free from the epidemic. Chemical examination fails to show whether a water is contaminated with this specific poison or not, and the difficulty attending a bacteriological examination has not enabled this test to be made available; yet the presence of other constituents in sewage, which gain access to the water at the same time as this specific micro-organism, are sufficient in most cases to permit of a conclusion being drawn from a chemical examination. Cholera is a disease due to a specific micro-organism contained in the evacuations of those suffering from the disease, and is propagated chiefly by means of drinking water infected with the specific poison. The evidence of its spread by specifically infected water has been well demonstrated during the recent epidemic at Hamburg, where those taking their drinking water from the Elbe, which was imperfectly filtered, and to which sewage had access, suffered severely from cholera, while those living on the outskirts of the city, and under similar conditions in every respect, except the source from which their drinking water was obtained, were not affected by the epidemic. In India, the testimony of all sanitary officers affirms the intimate connection which exists between cholera epidemics and impure and polluted drinking water.

As with enteric fever, so with cholera, the poison gains access to the water by the discharges of those suffering from the disease

being allowed to enter defective sewers, leaky cesspools, privies, etc., the contents of which infect the subsoil water or are carried direct into rivers or streams, from which drinking water is taken.

Malarial fever has been caused by drinking stagnant water and waters from marshes in tropical countries. In such waters, there is always a large amount of vegetable organic impurity present. In the Terai, in India, at certain seasons, it is dangerous to use the water for drinking purposes, unless it has been previously boiled. It has also been observed that the character of the fever is of a more severe type than when its introduction into the system is through the air; in these highly malarious places, it is difficult to assign exactly the influence polluted waters play in the causation of this disease, other factors being always present.

Ova of parasitic intestinal worms are found in water, and may gain access to the stomach by drinking the water. The more common forms are as follows :—*Tænia solium*, *Ascaris lumbricoides* (round worm), *Tænia mediocanellata*, *Bothriocephalus latus*, *Distoma hepaticum* (liver fluke of sheep), *Oxyuris vermicularis* (thread-worms). Also in tropical countries, the *Filaria sanguinis hominis* and *Filaria medinensis*. Metallic poisons are most usually caused by the absorption by the water of the metal used in the making of the service pipes, tanks, etc., by means of which the water is supplied or stored. The water may also be contaminated at its source by passing through a soil in which the metal is present, as in some mining districts, or a river may be polluted with metallic refuse from trade manufactures. Copper, zinc, lead, and arsenic are the most probable poisonous metals which may gain access to water in this way.

Purification of Water.—This subject may be considered as applying to (*a*) purification of water on a large scale as applicable to public water companies, before distribution of the supply, and (*b*) to domestic filtration as usually practised by the consumer in his own house. Water derived from the chalk undergoes a process of purification when the salts of lime are removed from the water before distribution for the purpose of rendering the water soft. Several methods have been used, but the basis of all of them is the addition of a measured quantity of milk of lime, calculated on the degrees of hardness of the water. Carbonates of lime and magnesia are soluble in water containing free carbonic acid. When a solution of fresh lime is added to such a water in proportion to the degree of hardness present, the lime combines with the excess of carbonic acid to form carbonate of lime, which is precipitated with almost the whole of the carbonate of lime originally held in solution by the water, and falls as a sediment, carrying down with it the organic impurities held in

suspension; this action of adding lime-water to remove the mineral matters (the salts of lime and magnesia) from a water may be expressed as follows:—

$$CaCO_3 + CO_2 + CaH_2O_2 = 2CaCO_3 + H_2O.$$

It is necessary to know the exact degrees of hardness in the water, and to use only sufficient milk of lime as will combine with the carbonic acid holding the chalk in solution, otherwise lime passes out into the distributing pipes. If an excess has been added, a few drops of a solution of nitrate of silver added to a small quantity of the water will produce a dark yellow colour, but only a white precipitate, if chlorides alone are present. In the Porter-Clark process, the suspended matters are removed by allowing the water to pass through a series of linen cloths under pressure. This has the advantage of rapidity, and removes the whole of the suspended matters effectually.

The permanent hardness of water is not touched by this process; this hardness is due to the soluble salts of lime or magnesia held in solution by the solvent properties of the water itself. Maignen's process is intended to act on this hardness, but it is difficult to say whether it does effect its purpose or not—it consists in adding to the water lime, sodic carbonate and alum—the alum causes a coagulation and precipitation of the organic matter, while the sodic carbonate attacks the salts of lime and magnesium. It is doubtful whether its effect on the fixed hardness of water is as adequate as its inventor claims. It has not come into general use.

Water is nearly always submitted to some process of filtration before distribution; it is extremely difficult to obtain at its source a water which needs no purification, and in the great majority of cases it is impossible to do so. It is the practice of most water companies to use sand and gravel as a filtering medium. Water is usually first passed into large reservoirs, where the suspended matters are allowed to subside by gravitation; these consist of mineral grit and clay in a state of fine subdivision and sand, all of which forms a deposit on the bottom of the reservoir. From thence it is led to filter beds made of sand and coarse gravel, the former being from two to three feet in thickness, and lying on one foot of gravel, and from this the water is collected into a storage reservoir for distribution. Downward filtration is much more effectual than the upward or lateral passage of the water through the filter. By these processes, two means are employed to purify the water, viz. mechanical and chemical. The mechanical processes consist in allowing the heavier particles to subside, and subsequently arresting the suspended matters on the surface of the filter beds.

Sand filtration has not much effect on the chemical constituents of the water, but oxidation of the organic matter does to a limited extent follow on passing water through sand filters. The chemical changes produced on water by filtration has up to a recent period been almost the sole test as regards the capability of the material to purify water; recent investigations show that all that is really necessary is that mechanical filtration shall be perfect. Sand, although its effect on the organic constituents in water, as gauged by chemical analysis, is limited, is very effective in holding back micro-organisms, which, if they are not the actual cause, are intimately associated with those diseases spread by the agency of water, such as enteric fever, cholera, dysentery, etc. The chemical action which takes place is probably due to the presence of a nitrifying ferment in the sand as well as to air in the interstices of the sand itself; this action is not, however, regarded as being of much importance. The mechanical action which frees the water from micro-organisms is largely assisted by the deposit of mud on the surface of the filters, and it is now recognized that in sand we possess a most powerful medium for removing germs from water. Two conditions are, however, necessary to obtain the best results; these are (1) that the sand should be of a certain thickness, not less than 30 c.m. (1 foot), and (2) that the water should not flow through it at a greater pace than four inches in one hour. The action of this filter is partly mechanical, partly vital; the mechanical action is confined to the holding back of the grosser substances which have not subsided, but remain suspended in the water; the vital action consists in the layer deposited on the surface of the sand which is charged with microbian life, and it is by these organisms, which are constantly increasing in number, and which penetrate the sand to a slight distance, that both the nitrification of organic matter and the arrest of other microbes is effected. From this it is evident that in order to preserve the power of these filters, the surface layer should not be removed with the object of cleansing it, for cleansing by removing the superficial membrane destroys the vital action of the filter; so long as water passes through it, it should not be disturbed. In some experiments recently undertaken in America, to test the power of sand filters in removing pathogenic bacteria, and especially that associated with typhoid fever from drinking water, it was found that 99½ per cent. of the applied bacteria were removed, and this goes to prove that these filters act efficiently when properly constructed as a safeguard against water-borne diseases. The rate of flow through the filter must not exceed six inches in one hour, and the rule should be that no water can be regarded as efficiently filtered that contains

more than 100 micro organisms in one cubic centimetre of the filtered water. But cases will arise in which it is necessary to purify water, and when no regular system of filtration as above described exists or is possible, simpler and often ruder methods are all that can be devised.

Distillation is one of the best means, and this is very frequently practised on board ships. It is necessary that the water taken for this purpose should be free from contamination. Water distilled from sea water taken in harbours to which sewage was admitted produced diarrhœa amongst those using it, possibly due to the large amount of free ammonia which came over with the distillate. The liability of such water also containing lead, taken from the pipes through which it passes, should not be overlooked.

Boiling is an excellent means for purifying water; the carbonate of lime is got rid of, and any hydrogen sulphide, and also some organic matter. It destroys most disease poisons, and it has been found that water which has been well boiled is safe to drink. Alum has been frequently used to purify water where there is much suspended matter; it acts best when calcium carbonate is present—calcium sulphate and a bulky hydrate of alumina precipitate being formed, which mechanically carries down the suspended matters with it; generally 5 or 6 grains of alum are sufficient to add to each gallon of water; it should be well stirred up in the water, and then set aside to allow the suspended matters to subside.

Animal charcoal is probably the material most in use for purposes of domestic filtration. Charcoal has the power of absorbing oxygen from the air, and probably condenses it within its pores. Its action is to oxidize organic matter, and to convert it into harmless products; this it does effectually, provided the charcoal is fresh, and if this was all that was required, or what resulted from its use, no better medium could be selected to purify water; but there are vital objections to its use as a filtering medium. It adds to water nitrogen and phosphates, both being the nutriment on which micro-organisms grow and develop. Its action on fresh, or, it may be said, vital organic matter is exceedingly feeble, while the charcoal itself readily absorbs impurities from the water or air, and is more of a danger than a safeguard against disease when it has been in use for a short time. The life of a charcoal filter is relatively short, depending on the quantity and quality of the water passed through it. Water cannot be stored with safety after filtration through animal charcoal, as micro-organisms develop rapidly in it. For these reasons it seems undesirable to use animal charcoal for the purposes of filtration; it is expensive, and not only in some cases inefficient, but dangerous.

Vegetable charcoal has little power in furthering the oxidation of organic matter in water; like all filtering media, it acts mechanically in holding back micro-organisms, but only to a limited extent. Both are inferior for the purposes of filtration to coke, which has considerable power in preventing micro-organisms passing through it into the filtered water, while it possesses no nutritive media that facilitates their growth; it retains this power for a considerable time.

Spongy iron, a substance obtained by roasting hæmatite ore, is a highly porous material; its action is partly mechanical and partly chemical; it arrests suspended matters, and any organic matters that may be present in solution are oxidized. It acts chemically on the water itself, setting oxygen free, which is taken up by the organic products in the water; its action is, however, slow, and it adds to the water salts of iron, which must be subsequently removed by allowing it to pass through "pyrolusite," a mixture of black oxide of manganese, gravel and fine sand.

This material adds nothing of an organic nature to water, which may be stored after filtration without risk of its becoming deteriorated. Its action is continuous, and it lasts for a considerable time, provided that the filter is kept constantly wet; if it is allowed to dry, the iron cakes and becomes useless; the water flowing down at the sides between the spongy iron and the filter is not exposed to the action of the iron. It is difficult to move this filter without disturbing the several layers of material of which it is composed.

Polarite, which has recently been introduced as a filtering medium, consists of the oxide of iron with some silica, alumina, and carbonates; its action on water is very similar to spongy iron, and it is in a more convenient form; it does not give up iron to water, or add anything to the filtered water which interferes with its subsequent storage. This material is used in filters known as "The Queen's Filter."

Manganous carbon, a mixture of animal charcoal and black oxide of manganese, is the medium in use in the "Morris" filter. It is a dark, granular material, much resembling animal charcoal; it oxidizes any organic matter present in the water, which does not appear to deteriorate on storage. Whether it is as lasting, or possesses advantages over other kinds of filtering media, is doubtful.

In Maignen's "Filtre Rapide," the filtering medium used is animal charcoal, which has been acted on with acetic acid, and any excess of acid neutralized with lime-water. It possesses no advantage over ordinary charcoal filters; the rapidity of filtration is the chief merit claimed for it; it retains its power of purifying water only for a short time; the object of treating the charcoal

with acid is to dissolve some of the calcic phosphate out of it, and thus to reduce the tendency to form a nutrient material for the growth of lower organisms. The results of experiments, however, show that it does not altogether remove this danger, if, indeed, it appreciably lessens it. It may here be noted that in the manufacture of animal charcoal, in order to limit the loss of carbon, the temperature is not raised sufficiently high to burn off all the nitrogenized matter, and this remains a source of danger which no subsequent treatment removes.

Carbolite, an artificial substance, the composition of which is not given, is used in the Royal Navy, and has been well spoken of. It adds neither phosphates nor iron to water, and combines the advantages of both the charcoal and spongy iron filters, while it does not favour the growth of organic life.

Silicated carbon filters, in which a block of prepared carbon covered by powdered silicated carbon is used, should not be relied on to purify water. The suspended matters tend to deposit on it, forming a slime on the surface, which contaminates the water it is supposed to purify. A filter which depends on a block of carbon alone is useless for the purposes of filtration.

Recent investigations go to show that the value of any filter does not so much depend on its action on the chemical constituents of a water supply as on its power of holding back micro-organisms, which are now generally admitted as being closely connected with the specific diseases. Sand, which has little effect on the chemical constituents of a water, is now regarded as one of the best mediums for holding back micro-organisms, and we have in the cholera epidemic at Hamburg a practical proof of its effect on water, by the absence of water-borne diseases, where this method of filtration has been efficiently carried out.

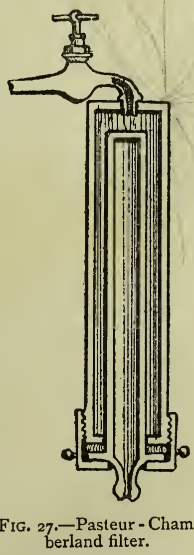


Fig. 27.—Pasteur-Chamberland filter.

Following on these lines, M. Pasteur devised a filter-tube made of fine porcelain, through which water is forced by pressure; the filtered water is then sterilized. Its action is purely mechanical, and the chemical constituents of the water are in no way affected by its passage through the "bougie," or tube.

Since these filters have been introduced into the French army, the number of attacks of enteric fever have diminished by 62 per cent., and as its use is extended it is expected that even more favourable results will accrue.

The Berkefeld filter is somewhat similar to the Pasteur-Chamberland; it is made in the same form, but the material is infusorial clay, which has considerable power in mechanically arresting any matters present in water. This form of filter allows water to pass more rapidly through it, and does not require so much pressure; the material is softer, but whether it will bear cleansing as effectually as the porcelain is doubtful; it is, however, an excellent material for the purpose. Both these filters fulfil the conditions which modern bacteriological knowledge teaches as necessary to purify water; it also shows that the older class of filters were not only in many cases useless but were absolutely mischievous. The objection to the use of these modern filters is that a head of water, or pressure, is required, and that the rate of flow is very slow; the former difficulty is got over by a simple mechanical contrivance introduced by the inventors, by which pressure is given to force the water through the filter; the latter objection can be overcome by using several in place of one "bougie" only.

These filters act on water precisely as sand filters act on a large scale; they sterilize the water—that is, the pores are so small and the current of water so finely divided that micro-organisms are unable to pass through. The filters have no action on the dissolved organic impurities in water, but it is of no less importance that water intended for drinking purposes should be free from these, as with such, no doubt, is associated the multiplication of micro-organisms, if not their virility and potency.

The rate of filtration through these filters depends in a large measure on the pressure of the water; the water passes from without inwards—a convenient method, as it allows of the deposit being washed from the surface of the tube, which can be easily done by removing the screw-tap and brushing the tube in hot water. It is recommended that occasionally it should be exposed to direct heat over a charcoal furnace, so as to ensure the total destruction of any organic life.

At a pressure of one atmosphere, a Pasteur-Chamberland filter will deliver from 2 to 3 quarts per hour; a Berkefeld filter about double that amount.

Water Analysis.

The results of a sanitary analysis of water must be considered in connection with many conditions, such as the locality and surroundings of the water, the depth or rate of flow of the river or lake, the season of the year, the conditions of the catchment, area, etc.; if wells, their proximity to the sea, their depth, and, if

possible, the strata through which they pass. Conditions such as these largely affect the interpretation of the results which a chemical analysis of a water gives. For example, the limit of free ammonia and chlorine allowed in a water taken from a deep well of 800 or 900 feet, would, if present in a surface well of 20 or 30 feet in depth, indicate contamination of a serious kind. The object of an analysis of water is to determine the amount of mineral and organic constituents, and to note for future examination the character of the suspended matters.

At the outset, a knowledge of the source of the water is necessary, whether a surface water or ground water. A surface water nearly always contains animal and vegetable life, while water from the deeper strata is usually devoid of life until it is exposed to the action of light and air in reservoirs, under which conditions it assumes in this respect the characters of a surface water.

Collection of Samples.—In order to secure that the results of an examination of water should be of value, care must be exercised in the collection of the samples. Winchester quart bottles, holding half a gallon, are very suitable for the purpose; the bottle used should be carefully cleansed with a little hydrochloric or sulphuric acid, and then thoroughly washed out with pure distilled water or some of the water to be examined. When a sample is taken, the bottle should be filled quite full, and just sufficient poured off so that a little air space is left under the stopper, care being taken that the inside of the neck of the bottle or the stem of the stopper be replaced untouched by the hand or wiped with a cloth. Corks should not be used except in great emergency, and then only if they are quite new and thoroughly rinsed in water before being used. No luting of wax plaster or similar material should be used.

In taking samples from streams, lakes, or reservoirs, the bottle should be submerged with its stopper in the water, and the stopper withdrawn 12 inches or more below the surface, so as to avoid collecting any of the water that has been in immediate contact with the air. If from a public water supply, the sample should be drawn from a hydrant in direct connection with the main, and not from a cistern or storage tank; if taken from a service pipe, the water should be allowed to run to waste for some minutes before it is collected, in order to remove that which has been standing in the pipe, the bottle should then be rinsed out at least three times, pouring out the water completely each time; the same practice should be adopted in the case of pumps.

Water should be examined as soon after collection as possible, and kept in a cool place not exposed to light.

It is important that with each sample the fullest information should be given of those conditions and surroundings which may influence the character of the water; especially must be noted the *source* of the water, whether from wells, rivers, cisterns, public supplies, etc. If a well, the depth and the depth of water in the well, whether steined or otherwise, the strata through which it is sunk, the position and distance as regards cesspools, privies, drains, etc., whether the land around is cultivated, whether a pump is attached, and if not, how the water is raised. If a cistern, how supplied; if by rain, the nature of the collecting surface and storage. If a public water supply, the source, and whether the water is supplied on the constant or intermittent system.

It should also be stated whether any disease is suspected to have been caused by the water, so that a bacteriological examination may be made if considered necessary. No point likely to afford information should be omitted.

Physical Examination of Water.—Water should be clear and free from turbidity. *Turbidity* is caused by the suspended matters in water, that which on standing for some hours settles to the bottom is its *sediment*. As a rule, surface waters are turbid, deep-well waters clear; the suspended particles may be finely divided clay, algæ or some other living form, animal or vegetable. The *colour* of water may be judged by looking through a stratum of water 12 inches deep, this can be done by using a tall glass placed on a sheet of white paper. Pure water is generally of a bluish or greyish colour. Yellow or brown waters are suspicious, as they frequently owe their colour to sewage, unless in peat districts or in places where iron is found, in which case they are not hurtful. The *taste* of water is a most uncertain guide; the taste depends almost altogether on the gases dissolved in the water, and not upon the soluble animal and mineral matters, unless these are in large excess. Any badly tasting water should be rejected. Taste also differs much in different persons. Common salt can only be tasted when 75 grains are added to 1 gallon of distilled water, and the other mineral constituents usually present must be large before they can be recognized. Iron is the only substance which can be tasted in small quantities.

The *odour* of water is best detected by heating it in a stoppered flask to 80° F. As a rule, the odour only lasts for a few moments, and should be judged by removing the stopper and smelling the water at once; it is sometimes a guide in polluted waters, and gives a clue to the origin of the pollution. Any offensive smell is sufficient to condemn a water.

The physical characters of a pure and wholesome water are

freedom from any marked colour and from suspended matters, a brilliant lustre, devoid of any taste or smell. In a large majority of cases, water possessing these characters is fit for drinking purposes.

It is not intended in this manual to treat fully the subject of water analysis, which requires much elaborate apparatus and considerable chemical knowledge, but a few qualitative and quantitative tests are given, capable of indicating the general characters of a water.

Qualitative Examination of Water.—The *reaction* of pure water is usually neutral. If acid and the acidity disappears on boiling, it is due to carbonic acid. If alkaline and the alkalinity disappears on boiling, to ammonia. If permanently alkaline, it is probably from sodium carbonate.

Litmus and turmeric papers are used to determine the reaction, which is usually red or brown.

Lime.—Add oxalate of ammonium; if lime is present, a white precipitate is formed: 6 grs. per gallon gives turbidity, 16 grs. a considerable precipitate.

Chlorine, with nitrate of silver and dilute nitric acid, gives a white precipitate: 1 gr. per gallon gives a haze, 4 grs. per gallon gives a marked turbidity, and 10 grs. a considerable precipitate.

Nitric Acid (nitrates). Add a solution of brucine (1 grm. in 1 litre of distilled water) and pure sulphuric acid. The sulphuric acid should be poured gently down the sides of the test tube to form a layer under equal parts of a mixed water and brucine solution. Half a grain of nitric acid per gallon gives a marked pink-and-yellow zone; or 2 c.c. of the water may be evaporated to dryness and a drop of pure sulphuric acid and a minute crystal of brucine dropped in—0·01 gr. per gallon can be easily detected.

Nitrous Acid (nitrites).—Nitrous acid decomposes iodide of potassium, and free iodine gives a blue colour with starch. Boil twenty grammes of starch intimately mixed with half a litre of distilled water; filter when cold, and add 1 grm. of potassium iodide. If a little of this solution is mixed with the water to be examined, and dilute sulphuric acid added, an immediate blue colour will appear, should nitrites be present; or Greiss's test may be employed. To 100 c.c. of the water add 1 c.c. of meta-phenylenediamine solution (made by dissolving 5 grms. of meta-phenylenediamine in 1 litre of distilled water, rendered acid with sulphuric acid and decolourized, if necessary, with animal charcoal) and 1 c.c. of dilute sulphuric acid (1 in 3). A yellow colour, changing to red, will appear in the water in half an hour if there be only one part of nitrous acid in ten millions of water.

Ammonia is detected by Nessler's solution; if present in water, a yellow colour or yellow-brown precipitate is formed. If in small quantity the colour should be observed through a column of water 4 or 5 inches in depth, the glass being placed on a white ground.

Iron.—Ferrocyanide of potassium (yellow prussiate) gives a blue colour with ferric salts, and ferricyanide (red prussiate) with ferrous salts. The water should be rendered acid with dilute hydrochloric acid, free from iron. A comparative test should be made with distilled water.

Hydrogen Sulphide, with a salt of lead, gives a black colour.

Oxidizable Organic Matter.—The water should be neutral or feebly acid; boil for 20 minutes, adding about 1 c.c. of a solution of chloride of gold (1 grm. to 1 litre). Colour varies from rose-pink through violet to olive or a dark violet to a dark precipitate, according to the amount of oxidizable matters present. If there is no nitrous acid in the water, the reaction may be considered due to organic matter; or add a strong solution of nitrate of silver and expose to diffused light; if organic matters be present, the darkening of the solution will take place rapidly.

Lead or Copper.—Place some water (100 c.c.) in a white dish, and stir with a rod dipped in ammonium sulphide; wait till colour is produced, then add a drop or two of hydrochloric acid. If the colour disappears, it is due to iron; if not, to lead or copper.

The following test is best applied to water concentrated to one-fiftieth part of its original volume:—

Magnesia.—Add oxalate of ammonium to precipitate the lime, then after filtration a few drops of phosphate of sodium, of chloride of ammonium and of liquor ammoniæ. A crystalline precipitate of triple phosphate appears within twenty-four hours.

The Quantitative Analysis of Water.

The chief points which require determination in an ordinary quantitative analysis are the total solids, the chlorides, the hardness and the organic matter as represented by what are called the free and albuminoid ammonia. If additional evidence as to the quality of the water is required, to these may be added the determination of the amount of oxygen absorbed, and the amount of nitrogen existing as nitrites and nitrates.

The main principle of a quantitative, or volumetric analysis, is the submission of the substance to be estimated to certain characteristic reactions, employing for such reactions, solutions of known strength; and from the volume of solution necessary

for the production of the reaction, determining the weight of the substance to be estimated by the application of the known laws of chemical equivalence.

To carry out any quantitative analysis, the first essential is the thorough comprehension of the simple relationship between liquids and solids. Owing to its uniformity and simplicity, in the following analytical methods, the metric system alone will be mentioned. Although tables of the various metric weights and measures are given in the Appendix, it may not be out of place here to emphasize the fact that, a cube of distilled water at its greatest density, viz. 4° C., or 39° F., whose side measures 1 decimetre, has exactly the weight of 1 kilogramme, or 1000 grammes, and occupies the volume of 1 litre, or 1000 cubic centimetres. In other words, 1 cubic centimetre, as a measure of volume equals or corresponds to 1 gramme as a measure of weight, and that

Grammes	of a subst.	diss. in	10	c.c.	of water	are x	parts in	10
,,	,,	,,	100	,,	,,	,, x	,,	100
,,	,,	,,	1000	,,	(1 litre)	,, x	,,	1,000
Decigrammes	,,	,,	,,	,,	(1 litre)	,, x	,,	10,000
Centigrammes	,,	,,	,,	,,	(1 litre)	,, x	,,	100,000
Milligrammes	,,	,,	,,	,,	(1 litre)	,, x	,,	1,000,000
,,	,,	,,	100	,,	of water	,, x	,,	100,000
,,	,,	,,	10	,,	,,	,, x	,,	10,000
,,	,,	,,	1	,,	,,	,, x	,,	1,000

It is most usual, in this country and on the Continent, to express the results of a quantitative analysis as parts per 100,000, or centigrammes per litre, or milligrammes per 100 cubic centimetres. This ratio will be adopted in the following analytical processes, while, for the sake of brevity, the term "cubic centimetre" has been written as c.c.

Occasionally, the expression grains per gallon is met with in English analysis. This is equivalent to parts per 70,000, as there are 70,000 grains in a gallon. The conversion of parts per 100,000 to grains per gallon, is, of course, readily performed by multiplying by seven-tenths, or by 0·7 ; and from grains per gallon to parts per 100,000, by multiplying by 10 and dividing by 7.

The Apparatus specially needed for making a Quantitative Analysis consists of—

1. *A pair of balances and weights*, according to the metric system. In these sets of weights, the larger ones represent grammes, the next in size decigrammes, and the next centigrammes. Small forceps are used for picking up and applying

these weights to the pans of the balance. The milligrammes are added by shifting a little piece of bent wire along the cross-beam of the balance, which has on it ten markings, numbered from 1 to 10, on either side of the pivot.

2. *A platinum dish*, capable of holding 120 c.c. of water.

3. One or more shallow *porcelain evaporating dishes*, capable of holding 300 c.c.

4. A small *porcelain crucible*, with lid, for igniting residues.

5. *A pestle and mortar*, for powdering reagents previous to solution.

6. One or more *retorts*, or boiling flasks.

7. A Graham's, or Liebig's *condenser*.

8. Six *Nessler glasses*, each capable of holding 150 c.c.

9. Glass *stirring-rods*.

10. Two glass-stoppered bottles, capable of holding 250 c.c.

11. Glass *funnels* for filtering.

12. A packet of Swedish *filter papers*.

13. A dozen *test tubes*, with stand, cleaner, and holder.

14. A *measuring flask*, to hold at least 1 litre and graduated in c.c.

15. Glass *burettes*, or graduated tubes, holding 20 c.c., and graduated in c.c., and tenths of a c.c. One of these should be mounted on a wooden stand, and be provided with a stopper at the top, and fitted with a stop-cock at the bottom.

16. A glass *pipette*, graduated to deliver 10, 20, 50, or 100 c.c.

17. An iron tripod.

18. One or more triangles of iron wire, lined with pipe clay.

19. A pair of small crucible tongs.

20. A long thermometer, graduated in either Centigrade or Fahrenheit degrees.

Standard Solutions required in a quantitative analysis, are solutions of definite strength, made by dissolving a given weight of a reagent, in grammes, in a definite volume of distilled water in cubic centimetres. These solutions are usually made by dissolving either a molecular weight of a reagent in grammes, or some decimal part of such weight in 1000 c.c. (1 litre) of water. The following abbreviations are often used to express the strength of standard solutions :—

N = a normal solution having 1 molec. weight in grammes per litre

$\frac{N}{2}$ = a semi-normal ,, $\frac{1}{2}$,, ,, ,,

$\frac{N}{10}$ = a deci-normal ,, $\frac{1}{10}$,, ,, ,,

$\frac{N}{20}$ = a viginti-normal having $\frac{1}{20}$ molec. weight in grammes per litre

$\frac{N}{100}$ = a centi-normal „ $\frac{1}{100}$ „ „ „

$\frac{N}{1000}$ = a milli-normal „ $\frac{1}{1000}$ „ „ „

Occasionally, in making standard solutions the equivalent hydrogen weight, or molecular weight of a reagent, cannot be taken, but its particular weight in a particular reaction in a given analysis has to be regarded. For instance, when using a solution of potassic permanganate, as an oxidizing agent, having the chemical formula $KMnO_4$, and the molecular weight of 158, and yielding five volumes of oxygen in a particular reaction, its normal solution is made by dissolving one-fifth of its molecular weight, $\frac{158}{5}$, or 31·6 grammes in a litre of water. In other instances, when the equivalent or combining weights of a substance are not identical with the atomic or molecular weights, the amounts taken are those of their equivalent weights. Thus, oxalic acid, $C_2H_2O_4 \cdot 2H_2O$, with an atomic weight of 126, is a bivalent substance, and its equivalent weight is one-half of its atomic weight; consequently, a normal solution of oxalic acid would be made by dissolving 63 grammes of the crystallized acid in 1 litre of distilled water. Similarly, phosphoric acid, which is a trivalent substance, would require, for the preparation of a normal solution of sodic phosphate, $Na_2HPO_4 12H_2O$, one-third of its molecular weight $\frac{358}{3}$, or 119·3 grammes being dissolved in 1 litre of distilled water.

Indicators.—In order to enable us to ascertain, by a change of colour or other marked effect, the exact point at which a given reaction is complete, certain substances, called indicators, are employed. The chief are as follows :—

(*a*) *Solution of litmus*, which turns red with acids and blue with alkalies.

(*b*) *Alcoholic solution of phenol-phthalein*, which is colourless with acids, but becomes red with alkalies.

(*c*) *Starch mucilage*, which turns blue in the presence of free iodine.

(*d*) *Solution of potassium chromate*, which gives a red with nitrate of silver, but not until all the chlorine or halogen present has entirely combined with the silver.

Estimation of Total Solids in a Water Sample.

The estimation of the total solids, by itself, is not of very great practical hygienic value, but affords a control over the other quantitative determinations. Take 250 c.c. of the water sample, place in an evaporating dish, and slowly evaporate down to 100 c.c., or less, carefully guarding against any of the solids remaining attached to the sides of the dish. Transfer the concentrated water and residue to either a small, clean, weighed crucible, or platinum dish. Evaporate to complete dryness, in air, water, or steam bath, at 100° C. So soon as capsule is cold, reweigh: the difference in weight will be the amount of *total solids*. A simple form of steam bath can be made by taking a common two-gallon tin can, fitting a perforated cork into its mouth, and passing a funnel through the perforation. The crucible is placed in the funnel, water boiled in the tin can, and a little roll of paper placed between the funnel and the crucible to let the steam pass out.

After the total solids have been determined, they should be slowly incinerated over a flame to dull redness, when any organic matter will give evidence of its presence by charring or by yielding dark fumes with the smell of burnt horn. Continue the incineration until nothing remains but a clear white mineral ash. If iron be present, the ash may be red; while manganese gives it a greenish tint. Having allowed the capsule to cool, weigh again; the excess weight now over that of the clean and empty dish represents the *fixed solids*, and the difference between them and the total solids gives the *volatile solids*.

Example.—Total solids, 250 c.c., dried as described—

	Grammes.
Weight of dish and residue	20·14
,, ,, alone	20·09
Difference being total solids in ¼ litre of water	·05
or ·05 parts in 250.	

This multiplied by 400 or 0·05 × 400 = 20 parts of total solids in 100,000.

Fixed Solids.

The above residue is incinerated as described.

	Grammes.
Weight of incinerated residue and dish	20·12
,, dish alone	20·09
Difference being fixed solids in ¼ litre of the water	0·03

This multiplied by 400 or 0·03 × 400 = 12 parts of fixed solids in 100,000.

Volatile Solids.

Total solids	20 parts per 100,000		
Fixed ,,	12	,,	,,
Difference being volatile solids	8	,,	,,

The total solids consist in most water samples of carbonates of calcium, sodium, magnesium, potassium and iron; sulphates and chlorides of sodium, calcium and magnesium; nitrites and nitrates of calcium, sodium and potassium; with occasionally some phosphates of potassium and sodium.

The volatile solids consist generally of ammonia salts, nitrites, nitrates, some of the chlorides and carbonates, with water from sulphate of lime and destructible organic matter.

The amounts of total solids vary from 3 or 4 to 50 or 60 parts per 100,000. Of these not more than 1·5 per 100,000 should be volatile or lost on ignition.

Estimation of Chlorides in a Water Sample.

For this purpose two solutions are required.

(1) *A solution of Potassium Monochromate*, made by dissolving 50 grms. of the salt in a litre of distilled water. Nitrate of silver is added until a permanent red precipitate is formed, which is allowed to settle and the clear liquid decanted off.

(2) *A deci-normal standard solution of Silver Nitrate*, made by dissolving 17 grms. of $AgNO_3$ (molecular weight being 170) in a litre of distilled water. This will be equivalent to one-tenth of the atomic weight of chlorine (35·5), or 3·55 grms. of chlorine and 1 c.c. of this solution will equal 3·55 mgms. of chlorine.

The process consists in taking 250 c.c. of the water sample, placing them in a white porcelain dish, and rendering them of a distinct yellow colour by means of two or more drops of the potassium chromate solution. From a burette, run in drop by drop some of the $\frac{N}{10}$ silver nitrate solution, stirring after each addition. The red silver chromate which is at first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. As each c.c. of the silver solution equals 3·55 mgms. of chlorine, the number of c.c. used indicates the mgms. of chlorine in 250 c.c. of the water, that is, parts per 250,000, and that divided by 2·5 or multiplied by 0·4 will give parts of chlorine for 100,000.

Example.—In 250 c.c. of water, rendered yellow with

potassium chromate, 1·5 c.c. of silver solution gave a permanent red tint; then—

$$\frac{1·5 \times 3·55}{2·5} = 2·13 \text{ parts of chlorine per } 100,000.$$

The purest water, as a rule, contains less than 1·5 parts of chlorine per 100,000. An increase may be due to sea water, percolation through salt bearing strata, to sewage or other impurities. Some deep wells often contain large quantities of chlorides; but generally an excessive presence of chlorine is a reason for suspicion unless a satisfactory explanation of its presence is obtainable.

Estimation of Hardness in a Water Sample.

The hardness of a water is conveniently determined by means of the soap test. Soap is an alkaline oleate resulting from the combination of an alkali with one or more of the fatty acids, *i.e.* oleic, stearic, or palmitic acids. When an alkaline oleate is mixed with pure water a lather is given almost immediately, but if lime, magnesia, alumina, baryta, iron or other similar substances are present in the water the soap forms oleates with these bases, and no lather is formed until these earthy bases are thrown down or used up. The hardness of a water depends upon the presence in it of more or less of these earthy bases, and the more they are present the greater will be the expenditure of soap to make a lather. Free carbonic acid has a similar effect. The soap combines in equivalent proportions with these bases, so that if a solution of soap be graduated by a solution of known strength of any one of them, it will be of equivalent strength for corresponding solutions of any of the others. Owing to magnesia having a tendency to form double salts with the fatty acids, the results are not quite so accurate as for lime or baryta. A certain amount of the hardness of a water is removed by boiling, hence it is usual to speak of the hardness present before boiling as total hardness, that remaining after boiling as fixed or permanent hardness, and that which has been dissipated by the boiling as the temporary hardness.

The total hardness in most drinking waters is caused by salts of calcium and magnesium with some free carbonic acid. Hence waters from the chalk, oolite, limestone, dolomite, and new red sandstone are apt to furnish the greatest degrees of hardness. Rain water, being free from these salts, is usually very soft. Many of the salts contributing to the total hardness are held in solution by carbonic acid, and when the water is boiled this is dissipated, causing these salts to fall to the bottom or form incrustations on

the sides of the containing vessel as insoluble salts. The chief of these are carbonates and sulphates of lime and magnesium with salts of silica, alumina, and iron when these are present.

The permanent hardness, or what still remains in solution, consists mainly of some sulphates, chlorides, and nitrates of calcium and magnesium, with a little iron and alumina.

The Soap solution for the estimation of hardness is best made by thoroughly dissolving by stirring and warming some soft soap in a mixture of 4 parts methylated spirits to 6 of distilled water and then filtering. This solution of soap should be standardized, that is, diluted or strengthened as the case may be, so that 2·2 c.c. of it exactly give a permanent lather when shaken up with 50 c.c. of a solution of nitrate of barium. Barium nitrate, $Ba(NO_3)_2$, has a molecular weight ratio to calcium carbonate, $CaCO_3$, of as 261 is to 100, and if 0·261 grm. of barium nitrate be dissolved in a litre of distilled water, that solution equals 0·1 grm. of calcium carbonate, and 50 c.c. of the same solution equals 5 mgms. of calcium carbonate. Now, if the soap solution be so made that 2·2 c.c. of it give a lather with 50 c.c. of the above barium nitrate solution, after deducting 0·2 c.c. for the amount of soap solution necessary to give a lather with 50 c.c. of distilled water, we get 2 c.c. of the soap solution to equal 50 c.c. of a barium nitrate solution, which again is equivalent to 5 mgms. of calcium carbonate, hence each c.c. of the soap solution equals 2·5 mgms. of calcium carbonate. Say, for instance, 35 c.c. of soap solution of unknown strength have been made, and on being standardized with 50 c.c. of the barium nitrate solution, it is found that 1 c.c. gives a lather in place of 2·2 c.c. being so required. Then as $1 : 2{\cdot}2 :: 30 : x = 66$; that is, 30 c.c. of it must be diluted up to 66 c.c. to give a soap solution, of which 1 c.c. shall exactly equal 2·5 mgms. of calcium carbonate. Of course, if the soap solution be found too weak it must be proportionately fortified with more soap until 2·2 c.c. exactly give a lather with 50 c.c. of the 0·261 Barium nitrate solution.

To determine the Total Hardness, take 50 c.c. of the sample and place in a stoppered shaking bottle. From a burette run in sufficient of the soap solution, until on being briskly shaken the contents of the bottle give only a faint dull sound with the formation of a quarter inch of fine uniform lather. This lather should show an unbroken surface after standing five minutes.

Suppose the addition of 2·4 c.c. of the soap solution have produced the necessary sound and lather. Deducting 0·2 c.c. as being necessary for the production of a lather in 50 c.c. of the purest water, we get 2·2 c.c. of the soap solution required by

50 c.c. of the water sample or 4·4 necessary for 100 c.c Each of these c.c. equals 2·5 mgms. of calcium carbonate; hence $4 \cdot 4 \times 2 \cdot 5 = 11$ mgms. of calcium carbonate in 100 c.c. of the water, representing a total hardness of 11 parts per 100,000, that is, 11° of hardness on the metrical scale. The original introducer of this soap test, Dr. Clarke, used to express the hardness as so many grains per gallon, hence 11° on the metrical scale are the same as 7·7° on Dr. Clark's scale, or $11 \times 0 \cdot 7 = 7 \cdot 7$ grains of calcium carbonate per gallon.

When the total hardness exceeds 4 c.c. of the soap solution, an over-estimation may be made as the excess of calcium and magnesium interfere with the formation of the characteristic lather. In these cases it is better to dilute 25 c.c. of the sample with 25 c.c. of distilled water, proceed as explained, when the net amount of soap solution used will indicate the hardness in parts per 100,000.

To determine the Permanent Hardness, place 100 c.c. of the sample in a flask and boil for half an hour. On allowing to cool, all the calcium and magnesium carbonate, with most of the iron, if any be present, will form a precipitate at the bottom of the flask, but some of the magnesium carbonate will have become redissolved. This precipitate will represent the temporary hardness for the most part, while the permanent hardness will still exist in the supernatant liquid. Carefully decant this clear liquid into a measuring glass, taking care not to shake up the precipitate. Measure it, and make up to the original bulk of 100 c.c. with distilled water. Then filter the whole through a fine filter paper and estimate the hardness, as explained above, in 50 c.c. of it. The result will be the permanent hardness, and the difference between that and the total hardness will represent the temporary hardness.

Say, 50 c.c. of the water thus treated required 1·6 c.c. of soap solution. Deducting 0·2 c.c. for lather, we get 1·4 c.c. and $1 \cdot 4 \times 2 \cdot 5 \times 2 = 7$ mgms. of calcium carbonate present in 100 c.c. of the water, and these 7 mgms. $CaCO_3$ represent the permanent hardness of 100 c.c. (100,000 mgms.) of the water sample, or, in other words, 7 parts per 100,000 of permanent hardness.

The total hardness was 11 parts per 100,000, therefore the *temporary hardness* equals $11 - 7 = 4$ parts per 100,000.

The total hardness of a water should not exceed 30 parts per 100,000, otherwise it is unsuitable for domestic purposes. What are called hard waters vary from 20 to 30 degrees on the metrical scale. A soft water from 8 to 15, while a very soft water may contain up to 6 or 8.

The permanent hardness should not exceed 6 parts per 100,000. Of course the greater the proportion of temporary to permanent hardness, the better, since the former is, to a large extent, remediable, while the latter is not.

The Estimation of the Ammonia in a Water Sample.

This and the following analytical procedures aim essentially at obtaining evidence of organic matter in water. The organic matter may be of either animal or vegetable origin, but in every case exhibits a natural tendency to resolve itself into simple parts, more particularly into ammonia and oxidized salts of nitrogen, such as nitrites and nitrates. The process known as that of Wanklyn, Chapman and Smith, recognizes two kinds of ammonia, namely the *free* or *saline* ammonia, and the *albuminoid* ammonia.

The free or saline ammonia represents the ammonia combined with carbonic, nitric and other acids, and also what may be derived from urea or other easily decomposed substances.

The albuminoid ammonia is that which can be derived from the breaking up of organic matter by the addition of a solution of strongly alkaline permanganate of potassium, and then boiling.

To estimate the ammonia in a water sample it is necessary to have the following solutions.

(1) *Nessler's Reagent.* This is a saturated solution of mercuric iodide in potassic iodide. It gives a yellowish tinge, with the faintest trace of ammonia, passing, if much ammonia is present, to the formation of a yellow-brown precipitate of the di-mercurammonium iodide. Nessler's solution is made by dissolving 35 grms. of potassic iodide in 100 c.c. of distilled water. Also dissolve 17 grms. of mercuric chloride in 300 c.c. of distilled water. Add the mercury solution to that of the iodide gradually until a precipitate of the red periodide of mercury just begins to be permanent. Then dilute up to a litre with a 20 per cent. solution of caustic soda: add more mercuric chloride, to render the solution "sharp," until a permanent red precipitate again forms: allow this to settle, and then decant off the clear solution.

(2) *A milli-normal standard solution of Ammonium Chloride.* Ammonium chloride represented by the formula NH_4Cl bears a ratio to ammonia, as represented by NH_3, of as 53·5 is to 17. Therefore if 0·0535 grms. of ammonium chloride be dissolved in 1 litre of distilled water, that solution will be a milli-normal one and equal 0·017 grms. of ammonia: and 1 c.c. of this $\frac{N}{1000}$ solution will equal 0·017 mgm. of ammonia.

(3) *An alkaline permanganate of potash solution* made by

dissolving 200 grms. of caustic potash and 8 grms. of potassium permanganate in 1100 c.c. of distilled water, and then rapidly boiling the solution down to 1 litre or 1000 c.c.

To determine the Free Ammonia, place 250 c.c. of the water sample in a retort and connect with a condenser. Apply heat to the retort and rapidly distil over the retort contents, catching the distillate in a Nessler's glass. As a rule the whole of the free ammonia will pass over in 130 to 140 c.c. of distillate, but before stopping the distillation a drop or two of the distillate should be received into a test-tube, one drop of Nessler's reagent added, and note taken whether the yellow-brown tinge due to the presence of ammonia is given. If Nessler's reagent indicates that no more ammonia is coming over, the light may be put out and distillation stopped, but if ammonia be still coming over, the distillation must be continued until it ceases to do so.

The whole of the ammonia having come over, the total amount of the distillate must be measured and recorded. Next take some of the distillate in a test-tube, add one drop of Nessler's reagent; if the resulting colour be very dark, it indicates much ammonia; if light, less of it. If the colour be not very deep 100 c.c. of the distillate must be placed in a Nessler glass, and to them added 1·5 c.c. of Nessler's solution; on stirring and allowing to stand for a short time a yellow to brown tint will be found. This colour is caused by the presence of ammonia, the precise amount of which we proceed to estimate in the following manner. To other Nessler glasses are added varying quantities of the standard ammonium chloride solution, each made up to 100 c.c. with distilled water and 1·5 c.c. of Nessler's reagent added. When a tint exactly corresponding with that given by the 100 c.c. of the water sample in the presence of 1·5 c.c. of Nessler's solution has been obtained, the quantity of standard ammonium chloride solution added is read off. This procedure of noting and comparing tints as given by different amounts of ammonia with Nessler's reagent is called "Nesslerizing."

Suppose, for example, from 250 c.c. of water placed in the retort, 140 c.c. have been distilled over before all the ammonia came over. On testing a little of this distillate with some Nessler's reagent, a very deep colour was given. 10 c.c. of the distillate are placed in a Nessler glass, made up to 100 c.c. with distilled water and 1·5 c.c. of Nessler's solution added. In a similar glass, 5 c.c. of the standard ammonium chloride solution after being made up to 100 with distilled water, and treated with 1·5 c.c. of Nessler's reagent are found to give the same yellow tinge. Then, if 10 c.c. of the distillate require 5 c.c. of the ammonium chloride solution, the whole 140 c.c. of the distillate representing

250 c.c. of the original water, will require 70, and as each cubic centimetre equals 0·017 mgm. of ammonia, the 250 c.c. of water sample contain $70 \times 0{\cdot}017 = 1{\cdot}19$ mgms. of ammonia, or parts per 250,000; this multiplied by 0·4 or divided by 2·5 gives 0·476 parts of free or saline ammonia in 100,000.

To determine the Albuminoid Ammonia. To the residue left in the retort, employed in the last process, add 25 c.c. of the alkaline permanganate solution and 25 c.c. of ammonia free distilled water. Proceed to distill over as before, and continue to do so until no more ammonia comes over; this it will generally cease to do after some 110 or 120 c.c. have been distilled. This ammonia is the so-called albuminoid, due to the breaking up of any organic matter present in the water under the influence of an oxidizing agent in the presence of a caustic alkali. The determination of the ammonia in this case is conducted in precisely similar fashion as for the free ammonia.

Suppose, 120 c.c. were distilled over; 100 c.c. were taken for the experiment: 4·5 c.c. of ammonia chloride solution were required to give the proper colour; then $4{\cdot}5 \times \frac{120}{100} \times 0{\cdot}017 \times 0{\cdot}4 = 0{\cdot}03672$ of albuminoid ammonia per 100,000.

In this process, before adding the alkaline permanganate solution to the residue in the retort, it is as well to boil it (the permanganate) for five minutes in order to get rid of any traces of ammonia which may be in it.

In drinking water, the free ammonia should not exceed 0·005 per 100,000, and the albuminoid ammonia not exceed 0·01 per 100,000. The presence of much free ammonia with excess of chlorine, nitrites and nitrates, usually denotes animal pollution. Much albuminoid, with a small amount of free ammonia, indicates vegetable contamination, particularly so, if the chlorides, nitrites and nitrates are low. Rain water often contains a large amount of free ammonia, probably derived from soot, and appears to be harmless. Deep wells often show much free ammonia and chlorides without necessarily indicating pollution; but the same amounts in a shallow well would be very suggestive of sewage or at least urine.

Estimation of Nitrites in a Water Sample.

When organic matter putrefies or decomposes, it becomes reduced to its absolute elements. Of these nitrogen is the chief, and this combining with hydrogen forms first ammonia, hence the presence, more or less, of free or saline ammonia in a water when at all polluted with organic matter, such as raw sewage. In-

the course of time, or as it percolates through the soil, the ammonia in the water acquires oxygen and gradually becomes partially oxidized to nitrous acid, HNO_2, or to nitric acid, HNO_3, which acids by combining with bases like calcium, sodium, or potassium form *nitrites* and *nitrates*. The oxidation of organic matter cannot go beyond the formation of nitric acid and nitrates, while the nitrous acid and nitrites mark an intermediate stage of imperfect oxidation.

The determination of nitrites and nitrates in a water is important as indicating either a pollution at some remote period with possibly dangerous matter, or more recently with a partially or completely oxidized sewage. Waters fouled by vegetable matter yield, as a rule, little nitrite or nitrate, chiefly because not only does vegetable decomposition yield relatively little nitrogen, but also because the natural tendency of all plant life is to remove both nitrites and nitrates from a water.

To determine the nitrites, we require the following three solutions.

(1) *A solution of sulphanilic acid*, made by dissolving 0·5 grm. of it in 150 c.c. of diluted acetic acid, sp. gr. 1·04.

(2) *A solution of naphthylamine*, made by dissolving 0·1 grm. of it in 20 c.c. of water, then filtering and mixing the filtrate with 180 c.c. of diluted acetic acid.

(3) *A milli-normal Standard Solution of Potassium Nitrite.* Owing to the unstable nature of this salt, it is necessary to prepare it specially for making up this solution. By the following chemical equation, $\underset{154}{AgNO_2} + \underset{74 \cdot 5}{KCl} = \underset{143 \cdot 5}{AgCl} + \underset{85}{KNO_2}$, it is seen that 154 parts of pure silver nitrite in the presence of 74·5 parts of potassium chloride are decomposed with the formation of 143·5 parts of silver chloride, and 85 parts of potassium nitrite or 46 of nitrous acid as represented by NO_2. Hence, if 1·54 grms. of pure silver nitrite be dissolved in hot water, decomposed with a slight excess of potassium chloride, allowed to cool, made up to a litre, we obtain a $\frac{N}{100}$ solution of potassic nitrite, equalling 0·46 grm. of nitrous acid as NO_2. If each 100 c.c. of this solution after standing, and subsidence of the silver chloride, be again diluted up to a litre with distilled water we get a $\frac{N}{1000}$ solution of KNO_2, equalling 0·046 grm. of NO_2, and each c.c. of which equals 0·046 of a mgm. of NO_2.

The **Process** consists in placing 100 c.c. of the water sample in a colour comparison or Nessler glass. By means of a pipette

2 c.c., each of the solutions of sulphanilic acid and naphthylamine are added to the water. If nitrites are present a pink colour is produced. Into another clean glass, 1 c.c. of the standard nitrite solution is placed, made up with nitrite free water to 100 c.c., and treated with the reagents as above. At the end of five minutes the colour of the two solutions are compared, and the colours equalized by diluting the darker.

Suppose, for example, the 100 c.c. of water sample is darker than the distilled water, containing 1 c.c. of the standard nitrite solution. It is necessary to dilute the water sample down to the tint given by the other: 60 c.c. of the 100 c.c. are taken and made up to 100 with distilled water: on comparison, suppose the colour to be still too deep: 70 c.c. of this diluted water is then taken and compared with the other. Presuming that the colours or tints now coincide, we get $100 \times \frac{60}{100} \times \frac{70}{100} = 42$ of the original 100 c.c. equal to 1 c.c. of the standard potassium nitrate solution, which again equals 0·046 mgms. of NO_2: therefore $\frac{100 \times 0·046}{42} = x = 0·085$ mgms. NO_2 in 100 c.c. or 0·085 parts per 100,000.

Had the glass containing the 1 c.c. of standard solution been the darker that could have been diluted down in a similar way, and the various fractions calculated as parts of 1 c.c. or equivalents of 1 c.c. in terms of NO_2.

The reactions in this process consist in the conversion of the sulphanilic acid into diazo-benzene sulphonic anhydride, by the nitrites present: this compound is in turn then converted by the naphthylamine into azo-α-amido-naphthalene-parazobenzene sulphonic acid. It is this last-named compound which gives the pink colour to the liquid.

It may be accepted as a good rule that, no water which shows the presence of nitrites is fitted for domestic use.

Estimation of Nitrates in a Water Sample.

If to a strongly alkaline water some aluminium foil be added, decomposition of the water ensues with the evolution of hydrogen. If nitrites or nitrates be present in the water, these salts are reduced by the hydrogen with the result that, on being boiled, their nitrogen is given off as ammonia.

The reagents required for the determination of the nitrates are (1) some thin aluminium foil, and (2) a solution of sodium hydrate. This is best made by dissolving 100 grms. of solid

sodium hydrate in 1 litre of distilled water. When cold, introduce a strip of aluminium foil, previously heated to just short of redness, wrapped round a glass rod. When the aluminium is dissolved, boil the solution briskly in a porcelain basin until about one-third of its volume has evaporated: allow it to cool, and make it up to its original volume with ammonia free water. The solution should be tested to prove the absence of nitrates.

The **process**, for determining the nitrates, consists in placing in a retort 100 c.c. of the water sample with 100 c.c. of the sodium hydrate solution, and adding to these a strip of aluminium foil: then leaving the same to stand for six or more hours. At the termination of this time, heat must be applied, after connecting the retort with a condenser, and the ammonia present in the flask contents distilled over in precisely the same way as described for estimating the free and albuminoid ammonia. The ammonia which will come over in the distillate, will consist partly of any free ammonia which may be present in the sample, partly of ammonia due to reduction of nitrites if any be present, and partly of ammonia due to a reduction of nitrates, if any be present. After elimination of the two former, the remaining ammonia will represent nitrates, and from it the quantity of nitric acid as nitrates can be readily estimated.

Thus, for example, presume that after placing 100 c.c. each of water sample and caustic soda solution with some aluminium foil in a retort and distilling, the whole of the ammonia is found to have come over in 120 c.c. This, on being tested, is found to give a deep tint with one drop of Nessler's reagent: according only 10 c.c. of the distillate are experimented with, and after Nesslerization are found to require 4 c.c. of the standard ammonium chloride solution, already explained when discussing the estimation of ammonia. If 10 c.c. require 4, then the whole distillate or 120 c.c. require 48 c.c. of the standard solution, each c.c. of which equals 0·017 mgms. of ammonia. Therefore $48 \times 0{\cdot}017 = 0{\cdot}816$ mgms. of ammonia in 100 c.c. of water, or parts per 100,000. This 0·816 parts of ammonia in 100,000 is the total ammonia yielded by the 100 c.c. of water sample: and includes not only free ammonia (if any) but also ammonia due to nitrites (if any) and nitrates.

Suppose this particular water sample to have already yielded 0·005 of free ammonia and 0·52 of nitrites as NO_2, both in parts per 100,000. The 0·52 of NO_2 is convertible into NH_3 in the ratio of as 46 is to 17, or $\frac{17 \times 0{\cdot}52}{46} = 0{\cdot}192$ of NH_3, and this added to the 0·005 of free $NH_3 = 0{\cdot}197$ of ammonia per 100,000

to be deducted from the total ammonia, before we get the NH_3 due solely to the reduction of any nitrates present.

This means $0{\cdot}816 - 0{\cdot}197 = 0{\cdot}619$ per 100,000 of NH_3, representing nitrates as NO_3. For the conversion of this NH_3 into terms of NO_3, we state the ratio of NH_3 to NO_3 as 17 is to 62 or $\frac{62 \times 0{\cdot}619}{17} = 2{\cdot}257$ mgms. of NO_3 in 100 c.c. of the sample or parts per 100,000.

If necessary, this NO_3 can be expressed as nitrogen $(N = 14)$: or $\frac{14 \times 2{\cdot}257}{62} = 0{\cdot}509$ of nitrogen. Similarly the nitrites and free ammonia might be expressed as so much nitrogen, by a reference to the ratio between their combining weights.

No water used for drinking purposes should contain more than $0{\cdot}1$ part per 100,000 of nitrogen in the form of nitrates, unless, of course, the geological strata are such as can be legitimately regarded as the source from which the water derives these salts.

Estimation of the Oxygen Consuming Power of a Water Sample.

Although by itself of little value as a measure of the organic impurity, still the power of consuming or affinity for oxygen which a water sample has, when taken in conjunction with other analytical facts, is often a material aid in forming an opinion as to the quality of any particular water. Much of the organic matter present in water is capable of oxidation, but since the ease of oxidation bears no constant ratio to the nature of the organic matter, its estimation affords no very reliable index to the real pollution present. In all the efforts to judge the oxidizible organic matter, advantage is taken of the fact that, in the presence of organic substances, permanganate of potassium $KMnO_4$, freely parts with its oxygen until all the permanganate has been reduced to hydrated manganese dioxide: thus, $2\,(KMnO_4) = K_2MnO_4 + MnO_2 + O_2$: in everyday life, this change is marked by the pink colour which this salt originally gives to water being replaced by a brown. Unfortunately, different substances reduce different proportions of permanganate, and slight variations in temperature and acidity or alkalinity materially influence the readiness with which the permanganate parts with its oxygen.

To determine the Oxidizable Organic Matter, use is best made of what is known as Tidy's process. This process is based

upon the chemical fact that in the presence of an acid and heat, the following decomposition of permanganate takes place :—
$4(KMnO_4) + 6(H_2SO_4) = 2(K_2SO_4) + 4(MnSO_4) + 6(H_2O) + 5O_2$, or in other words 632 parts of potassium permanganate yield in the presence of sulphuric acid 160 parts of oxygen :—

For Tidy's process, the following solutions are necessary :—

1. *Standard Potassium Permanganate Solution.*—Since 632 parts of the salt with an acid yield 160 parts of oxygen, then 0·395 grm. of potassium permanganate, if dissolved in a litre of water, will be equivalent to 0·1 grm. of oxygen. This constitutes the standard solution, being a $\frac{N}{1000}$ one, 1 c.c. of it used with acid yields 0·1 mgm. of oxygen.

2. *Potassium Iodide Solution.*—A 10 per cent. solution in distilled water.

3. *Sodium Hyposulphite Solution.*—One gramme dissolved in a litre of distilled water.

4. *Starch Solution.*—One gramme of starch, mixed with $\frac{1}{2}$ litre of distilled water, boiled for five minutes and filtered.

5. *Strong Sulphuric Acid.*

In performing this process, the late Dr. Tidy recommended two determinations to be made, namely, one of the oxygen absorbed after fifteen minutes' exposure at a temperature of 80° F., and one after four hours' exposure at the same heat. He considered that during the first quarter of an hour, the more or less putrescent easily-oxidized animal organic matters were oxidized, while the oxidation of the vegetable organic material did not take place till after four hours or so. Practically, as much information as can be gained is obtained at the end of fifteen minutes; therefore, except in special cases, the second observation after four hours is hardly necessary. If required, it is performed exactly in the same manner as the shorter exposure.

Into a stoppered bottle, capable of holding from 300 to 400 c.c., place 250 c.c. of the water sample, and heat in a water bath to 80° F. (26·7 C.); when the required temperature is reached, run in 3 c.c. of sulphuric acid and 10 c.c. of the permanganate solution. A pink colour will result. Maintain the bottle contents at 80° F., carefully noting whether the pink tint is discharged; if the tint disappear add more permanganate. At the end of fifteen minutes, add to the water three drops of the iodide of potassium solution. Owing to there being a certain amount of oxygen available from the permanganate, as previously explained, this will liberate iodine from the iodide, with the result that the pink-coloured bottle contents will now become yellow: thus, $5O_2 + 20KI + 10H_2O = 20KHO + 10I_2$. The quantity of iodine

set free will, of course, be dependent on the amount of potassium permanganate remaining unreduced in the water. If the iodine set free is absolutely dependent upon the amount of permanganate left unreduced by the organic matter in the water, it is obvious that any estimation of the iodine liberated will be a measure of the unused oxygen, and this deducted from what was rendered available by the original quantity of permanganate added, will give a measure of the oxidizable organic matter in the 250 c.c. of water.

We proceed to make these estimations in the following manner. To the iodine-tinted water, the hyposulphite solution is gradually added with the object of reducing it: thus, $I_2 + 4NaHSO_2 = 2NaI + Na_2S_4O_6 + 2H_2O$. In order to know exactly when all the free iodine has been removed from the water, an indicator in the form of 1 c.c. of the starch solution is added; this, so long as any free iodine is present, will give a blue tint. Therefore, continuing the addition of the hyposulphite, we stop the moment all the blue colour has gone, and read off the actual amount of hyposulphite used.

Unfortunately, hyposulphite of soda is a very unstable salt, and its particular value as a reducing agent needs to be judged, at the time of each experiment, by means of a control observation of its power upon an identical quantity of permanganate in distilled water, as was used for the unknown sample. Accordingly, into a similar bottle, 250 c.c. of distilled water are placed, heated to 80° F., 3 c.c. of sulphuric acid, and exactly the same amount of permanganate as was used for the water sample added, and the whole kept at 80° F. for fifteen minutes. In this bottle, owing to there being no organic matter, practically the whole of the oxygen liberated from the permanganate under the circumstances will be unconsumed, and consequently, on the addition of three drops of potassium iodide, more iodine will be liberated, and more of the hyposulphite will be required to reduce it. The iodide, the starch, and the hyposulphite are added precisely as in the other experiment.

So soon as all the iodine has been removed, as shown by the disappearance of the blue colour, the amount of hyposulphite used is read off; its volume will represent, for the time being, the actual reducing value of the hyposulphite for the precise amount of permanganate used or added in the experiment. And the difference between the amount of hyposulphite solution needed to reduce the x amount of potassium permanganate in this pure distilled water, and that required for the same amount which has been more or less decomposed or reduced by oxidizable organic matter in the water sample, will represent the quantity of oxygen consumed by such oxidizable matter.

Example.—Say 10 c.c. of $KMnO_4$ in the distilled water has used up 40 c.c. of the hyposulphite solution; therefore 40 c.c. of the hyposulphite may be considered as equivalent to 10 c.c. of permanganate, or 1 mgm. of oxygen, because each c.c. of $KMnO_4$ equals 0·1 mgm. of oxygen.

Another 10 c.c. of $KMnO_4$, in the unknown water sample, used up, say, 32 c.c. of hyposulphite solution; therefore an amount of oxygen equivalent to the difference between 40 and 32 or 8 c.c. of hyposulphite solution has been taken up by the organic matter. But if 40 c.c. of hyposulphite equal 1 mgm. of oxygen, then 8 c.c. equal 0·2 mgm. of oxygen. This means that 0·2 mgm. of oxygen is taken up by 250 c.c. of the water sample, or parts per 250,000; this multiplied by 0·4 equals 0·08 parts of oxygen consumed by the organic matter per 100,000.

In performing this process, the permanganate added must be sufficient to create a pink colour, which remains distinctly permanent at the end of the heating. If the four-hour test be applied, it may be necessary to make repeated additions of the permanganate solution. The *total* quantity actually used must be carefully noted, and the same amount of course employed in the distilled water experiment.

In endeavouring to interpret the results of the oxygen process, it must be borne in mind that besides organic matter, iron salts, nitrites and sulphuretted hydrogen will reduce permanganate of potassium, and these latter, if present, must be duly allowed for. It is difficult to distinguish between the oxygen consumed by the nitrogenous and the non-nitrogenous organic matter. Roughly speaking, the four-hour experiment gives information as to the total amount of oxidizable organic matter, while the fifteen minutes' reaction is valuable as indicating the proportion of putrescent or readily oxidizable and presumably dangerous material. Peaty waters consume large quantities of oxygen; hence, as in all other attempts to measure the organic matter in a water sample, the results of the oxygen process must be considered in conjunction with the other analytical data and the source of the water.

In a general way, it may be said that waters of great organic purity will not consume more than 0·05 of oxygen per 100,000 in fifteen minutes at 80° F., and that when the oxygen consumed exceeds 0·1 per 100,000 the sample may be considered of doubtful purity.

The following table gives the general characteristics of some good and bad waters, with their analytical results expressed as parts per 100,000:—

	Good and Pure.				Indifferent or Suspicious.			Impure.
	Upland surface water from uncultivated lands.	Deep well-water from the chalk.	Water from spring in the new red sandstone.	Rain-water collected in the country.	Rain-water collected in a town.	Water from a shallow well.	Upland surface water from cultivated lands.	Water from a shallow well near a leaky cess-pit.
Total solids	13·40	26·40	28·69	2·16	2·80	20·60	31·24	22·70
Volatile solids	1·80	2·50	1·34	0·80	1·00	4·30	2·30	5·10
Chlorine	1·71	2·60	2·10	0·10	0·40	3·00	1·80	4·50
Total hardness	2·90	21·80	18·80	0·80	1·10	6·70	16·40	7·30
Fixed hardness	1·60	4·60	10·70	—	0·90	4·80	6·10	4·20
Free ammonia	—	0·005	0·002	0·02	0·040	0·003	0·005	0·012
Albuminoid ammonia	0·012	0·003	0·004	—	0·002	0·012	0·006	0·020
Nitrites	—	—	—	—	—	0·060	0·030	0·090
Nitrates	0·020	0·100	1·50	—	0·034	1·800	1·370	2·700
Nitrogen as nitrites and nitrates	0·0045	0·022	0·33	—	0·008	0·425	0·315	0·637
Oxygen consumed	0·080	0·020	0·050	0·060	0·2	0·150	0·055	0·210

CHAPTER III.

FOOD.

The Classification, Nature, and Uses of Food Stuffs.—We may define the word *food* as including everything we take into our bodies which either directly or indirectly goes to the growth and repair of the body or to the production of energy or functional activity in any form. This definition necessarily includes not only all the ordinary articles consumed in eating and drinking, but also water and air. Since, however, the taking in of air into our lungs is mainly an involuntary act, it is customary not to include air and its constituents taken into our bodies by the lungs as foods, but to strictly limit the term *food* to substances taken by the mouth into the digestive tract.

It is convenient to speak of the various substances which constitute food as *proximate principles*, because, consisting as they do of carbon, hydrogen, oxygen and nitrogen, combined more or

less into highly complex bodies, they really are elementary constituents or proximate principles of the human organism. These elementary or proximate principles may be conveniently classified as follows:—

- Organic.
  - Nitrogenous, such as the proteids or albuminous bodies.
  - Non-nitrogenous
    - Fats or hydrocarbons.
    - Starches, sugars, or carbohydrates.
    - Vegetable acids.
- Inorganic. Mineral salts.

Both these great classes are present in all ordinary articles of diet, no matter whether they be derived from animals or vegetables. In the case of man's food, we must add to the above a third group, which includes the so-called "food accessories," such as tea, coffee, alcohol, etc.

It must be noted that the simplest division of the organic constituents of food is into the nitrogenous and the non-nitrogenous, or those which contain nitrogen and those which do not. Now, the proteids alone contain nitrogen. Just as the greater part of the air is made up of nitrogen, so is the greater part of our body (bone excepted) made up of proteid, or nitrogen containing substances. A large amount of nitrogen in the form of urea, uric acid and other substances, is daily being lost from our bodies by the urine; and to repair this loss, a daily intake of nitrogenous food is required. The only form of nitrogen food which the body can make use of is that of proteid or albuminoids. A plant equally needs nitrogen, but this it obtains from the ammonia and nitrates of the soil, which are much simpler bodies than proteids.

All **proteids** are composed of carbon, hydrogen, oxygen, nitrogen, and sulphur, with occasionally a little phosphorus. Their general percentage composition may be taken as being: nitrogen, 16 parts; carbon, 54 parts; oxygen, 22 parts; hydrogen, 7 parts; and sulphur, 1 part. The proteids, when regarded as foods, are divisible into two great groups, according to their nutritive value. The more nutritious one is the group of true proteids, consisting of albumin, myosin, glutin, casein, legumin, and peptones; in them, the proportion of nitrogen to carbon is nearly as 2 is to 7. The other, or less nutritious, group is sometimes called the albuminoid group; its members include substances obtained only from animals, such as gelatin, chondrin, ossein, and keratin; in them, the proportion of nitrogen to carbon is as 2 is to $5\frac{1}{2}$.

Albumin constitutes the essential constituent of that substance which, called by physiologists protoplasm, really is the physical basis of life. In its most familiar form, we find it as egg albumin, or that which makes up nearly the whole of the white and a third

of the yolk of an egg. A similar body is serum albumin, or the chief solid constituent of blood serum.

Myosin, or muscle albumin, is present largely in muscle, from which it can be obtained by first washing out all the serum, then dissolving the mass in a 10-per-cent. solution of common salt, and dropping the semi-solid substance into a vessel containing distilled water, in which it forms a flocculent deposit.

Glutin is an insoluble proteid obtained from the seeds of most of the cereals. If a little flour be placed in a piece of muslin and a stream of water be allowed to run on it, as the water leaves the paste it will be quite milky, and if collected, the white powder which makes it milky will settle at the bottom of the vessel. The powder thus obtained from the flour is starch. The substance which remains in the muslin is not at all like flour or dough, but is a sticky substance, and is really nearly pure glutin.

The three foregoing substances have one common feature, namely, that they are coagulated by heat; and when so coagulated, as in cooking, they are not dissolved by either water or dilute acids and alkalies, but are readily dissolved and digested by the gastric juice of the stomach.

Casein is the nitrogenous solid present in milk, familiar to us all as the curd which forms when an acid is added to milk.

Legumin is a proteid very much resembling casein, but present chiefly in the seeds of beans and peas.

Peptones and *albumoses* are forms of proteids very closely related one to another, and though probably widely distributed in vegetables and plants, are chiefly formed by the action of pepsin upon ordinary proteids. The albumoses are, strictly speaking, precursors or bodies formed before peptones during digestion of proteids. The peptones are remarkable for their extreme diffusibility and ready absorption by the alimentary canal. Owing to their easiness of digestion, these forms of proteid are now largely given in the various kinds of partly artificially digested foods for the sick, though it must be remembered that they do not possess the same nutritive value as the ordinary proteids of food. Both casein and the peptones have the common characteristic of not being coagulated by heat.

As closely allied to the foregoing may be mentioned *syntonin* or acid albumin, which exists in some meats, and also *alkali albumin*. These are formed by the action of dilute acids and alkalies on the ordinary proteids, and are not precipitated from solutions by boiling.

The albuminoids, such as gelatin, chondrin, etc., are bodies closely resembling the albumins, but probably not existing as such in the tissues of the body, but only obtained from them by

prolonged boiling. These bodies are easily dissolved in hot water, and yield more or less the same products after digestion as the proteids, but appear, on the whole, to have a less nutritive value than them. Gelatin is obtained by boiling bones and cartilage. Experiments go to show that life cannot be sustained when this is the only nitrogenous matter taken as food; although, if used alone, it appears to have only small nutritive value, still, if other proteids be taken with it, it has some value. Glue of all kinds is really a form of impure gelatin obtained by boiling the horns and hoofs of animals.

From what physiology teaches us, we know that the cells which go to make up the animal body are formed of "protoplasm," and that consists of the proteids taken in as food; so that, to all intents and purposes, the nutrition of the nitrogen containing tissues means the nutrition of the body. As to the precise part played by the proteids of our food in the nutrition and work of the body, considerable misconception existed until within comparatively recent times. This was mainly due to the teaching of Liebig, who, assuming that each organ in the exercise of its function consumed a certain proportion of its own substance, and that muscle being essentially a nitrogenous tissue, maintained that our need of proteid food was in a direct ratio to the amount of muscular activity exhibited. If this were the case, then the elimination of urea and uric acid, which together practically represent all the nitrogenous matter changed in the body, should be proportional to the amount of work done; but such is not the case. On the contrary, as shown by Voit, the greater or less amount of nitrogen got rid of by the kidneys depends, not upon the amount of muscular work done, but really upon the quantity of nitrogen taken in as proteid food; so that the main part of the proteid substances taken in as food is, at least for a time, stored up in the body generally, to be used up as required by the tissues for their repair and growth, and, in a limited sense, also as a source of some of the fat of the body and of the glycogen found in the muscles and liver; any excess over these needs being at once metabolized and eliminated. From this it is evident that the proper supply of the proteid food stuffs is of the first importance, though an excess of proteid food throws an excess of work on the nitrogenous tissues. The natural law seems to be that to preserve health the nitrogen taken must equal that destroyed.

Fats or Hydrocarbons.—These are compounds of glycerine with the fatty acids, oleic, stearic, and palmitic acid, etc. They all contain carbon, hydrogen, and oxygen, but no nitrogen, and may be represented by the general formula $C_{10}H_{18}O$. The proportion of oxygen in them, however, is insufficient to combine

with all the hydrogen present so as to form water. When taken as food, the fats not only repair or renew the fatty tissues, but yield energy and heat, owing to their oxidation into carbonic acid and water. In addition to this, they help in the proper digestion of the other foods, possibly owing to their power or influence in promoting the flow of bile and the pancreatic juice. When consumed as food, the fats are not acted upon by either the saliva in the mouth or by the gastric juice of the stomach, but reach the small intestine more or less unchanged, where they become emulsified by the bile and pancreatic juice, and in the emulsified state are readily absorbed by the lacteal vessels. Fats are found in the majority of diets of all nations, and by those living in very cold countries, the amount consumed is very large. When hard work is being performed, an increase of fatty food is demanded.

Carbohydrates.—This is a large group, and embraces all the various starches and sugar, also cellulose and gum. Like the fats, these contain no nitrogen, but only carbon, hydrogen, and oxygen; these two latter elements exist in sufficient proportion to form water, hence their name, "carbohydrates." In the main, the carbohydrates are derived from the vegetable world, though lactose, a kind of sugar, is found in milk, and glycogen, a form of starch, exists in the liver.

The *starches* constitute a large class of foods, and, existing in the form of granules, constitute the chief portion of the seeds of the various cereals and potatoes. Starch combines with iodine to form a blue colour, constituting thereby a simple test for its presence. In cold water or alcohol, starch is insoluble, but at about 180° F. water causes the granules to burst and swell out. Heat and dilute acids convert starch into a gum-like substance, called dextrine, and, if carried further, into grape sugar. A similar action is produced upon starch by the saliva and pancreatic juice. Starch, represented by the formula $C_6H_{10}O_5$ under the influence of these juices, takes up an atom of water H_2O and becomes $C_6H_{12}O_6$, or grape sugar; this, on being taken up by the blood, is carried along the portal vein to the liver, where it is deposited as glycogen or liver starch, to be subsequently supplied to the system as the needs of the body demand. When exposed to the action of diastase, which is a peculiar ferment existing in all germinating seeds during growth (malted barley, for example), starch is converted into another form of sugar called maltose $C_{12}H_{22}O_{11}$.

The sugars belong practically to one or other of two kinds, namely, the sucrose or cane-sugar variety, and the glucose or grape sugars.

Cane sugar, or sucrose, is the ordinary sugar of commerce,

extracted chiefly from sugar cane. It is a crystalline body, not soluble in either absolute alcohol or ether, though freely so in weak alcohol; in water, its solution is thick and syrupy. Cane sugar is represented by the formula $C_{12}H_{22}O_{11}$, and to its group belong *maltose* and *lactose*. The former is a low form of sugar, the final product of the action of diastase on starch. Lactose $C_{12}H_{22}O_{11}$, or sugar of milk, is a variety of sugar found only in the milk of the mammalia. It is only partially soluble in either hot or cold water, and not directly susceptible of alcoholic fermentation except under the action of weak acids which convert it into grape sugar. In the presence of any decomposing proteids, lactose is transformed into lactic acid. One of the most remarkable features connected with the sugars is their power of deflecting a ray of polarized light to either the right or left. Cane sugar has a specific rotating power of 73°·8 to the right; maltose has a similar power of 150° to the right; while lactose has an action on polarized light in the same direction of 58°·2.

Grape sugar, or *glucose*, also called dextrose, or starch sugar, exists ready formed in grapes and other fruits, but is also made on a large scale from starches either by treating them with dilute acids or by the action of malt; in fact, grape sugar is the first product during the fermentation of either cane sugar, milk sugar, or starch, and is represented by the formula $C_6H_{12}O_6$. When a solution of cane sugar is boiled with dilute mineral acids, the sugar is split up into two glucoses, thus—

$$\underset{\text{Cane sugar.}}{C_{12}H_{22}O_{11}} + \underset{\text{Water.}}{H_2O} = \underset{\text{Dextrose.}}{C_6H_{12}O_6} + \underset{\text{Levulose.}}{C_6H_{12}O_6}$$

One of these rotates polarized light to the right, hence called dextrose; the other rotates it to the left, hence called levulose. This mixture of dextrose and levulose is often called invert sugar, because the polarization of light is the opposite of that of cane sugar, for although dextrose or glucose rotates to the right some 57°·6, and levulose to the left, yet the latter rotates so much more, namely, 108°·8, that the combined solution polarizes distinctly to the left. Glucose or dextrose is soluble in both water and dilute alcohol, and is directly broken up or fermented by yeast into alcohol and carbonic acid; thus—

$$\underset{\text{Grape sugar.}}{C_6H_{12}O_6} = \underset{\text{2 Alcohol.}}{2\,(C_2H_6O)} + \underset{\text{2 Carbonic acid.}}{2\,(CO_2)}.$$

Among carbohydrates must be included cellulose and pectose. *Cellulose* constitutes the chief framework of plants, it is quite insoluble, and without any dietetic value. In a similar way, *Pectose* or vegetable jelly is found in various ripe fruits, being really a later stage of the insoluble body present in most unripe fruits and known as pectin. Its precise composition is unknown.

In their physiological use, the carbohydrates closely resemble the fats or hydrocarbons; being directly used in contributing to the maintenance of animal heat and the production of force or energy as well as the formation of fat. They, however, differ from the fats in that the amount of them consumed as food is proportional to the quantity of CO_2 excreted; with fats this is not so. Performing as they do in the body, similar functions, it has been surmised that fats and carbohydrates might be mutually interchangeable as articles of diet. On this point, although the evidence is not very precise, the general consensus of opinion is that they are not wholly interchangeable, though perhaps practically so as instanced by the fact that owing to their relative cheapness carbohydrates largely replace, but not completely, the fats in the diets of the poor. A certain degree of health can be maintained on a diet of proteids, fats, salts and water, but the absolute withdrawal of fats and a bare substitution of carbohydrates for them rapidly leads to a loss of vigour and health. The truth probably lies in the acceptance of an admixture of both fats and carbohydrates in the diet.

Vegetable Acids.—These, though not strictly speaking foods, play so important a part in preserving the health of man that they demand some considerable notice. The chief among them are tartaric, citric, malic, oxalic and acetic acids. *Tartaric acid* $C_4H_6O_6$ exists largely in grape juice chiefly as the acid tartrate of potassium; *Citric acid* $C_6H_8O_7$ is found in oranges, lemons, and gooseberries; *Malic acid* $C_4H_6O_5$ is met with in fruits belonging to the rose order, such as apples and pears; *Oxalic acid* $C_2H_2O_4$ is present largely in rhubarb and sorrel; *Acetic acid* $C_2H_4O_2$ constitutes the active element in vinegar. Except it be the latter, all these vegetable acids contain more than sufficient oxygen to convert all their hydrogen into water. These acids exist mainly in fresh fruits and vegetables, either as free acids or in combination with alkalies as alkaline salts, and, when taken into the body, form carbonates, which exercise a controlling influence in preserving the alkalinity not only of the blood but other fluids; they also furnish a small amount of energy and heat by oxidation. Their absence for any length of time from any dietary leads to a peculiar lowering or weakening of the blood, resulting in the disease called scurvy. It is possible that some of these acids are not only derived from fruits and vegetables, but also in a small degree from the splitting up of carbohydrates, so that even the latter, in an indirect way, help in maintaining the alkalinity of the blood and other animal fluids.

Mineral Salts.—Among the mineral salts which constitute a part of the proximate principles of food must be included

chloride of sodium or common salt, the phosphates of lime, potash, soda and magnesium, along with small quantities of sulphates and possibly iron. These, in their various and respective ways, are essential for the repair and growth of all parts of the body. The uses of the chlorides as typified by common salt, are very important. The complete withholding of ordinary salt from food leads to rapid disease, and even death. The chlorides generally keep in solution the globulins of the blood and other fluids, while at the same time are the source of the hydrochloric acid of the gastric juice, and materially aid in the solution of albumin. The phosphates of lime, potash and magnesia contribute, especially in the young, to the formation of bone; while iron forms an important part of the hæmoglobin of the red blood corpuscles.

If we remember that 64 per cent. of the body consists of *water*, the need of it is not difficult to understand. Though a portion of it is obtained by the oxidation of the hydrogen in the tissues, still the greater part is derived from that taken in as food. In the body itself, water serves chiefly for the solution and conveyance of food to different parts of the system, for the excretion of effete products, for the equalization of heat by evaporation, both from the lungs and skin, as well as for the regulation of all the chemical and mechanical functions of the body.

The Nutritive Value of the Food Stuffs.—In the preceding pages we have learnt the part which the various food stuffs play when taken into the body; it is now necessary to learn their nutritive value. To begin with, if we lift a weight by our hands, muscular force is employed in the act, and the energy evolved in this or any other muscular action must have its origin or source in something. As a matter of fact, the energy so evolved has its source in the material which has been supplied to the body in the form of food. Every process of our bodies, no matter whether it be the moving of a hand or a foot, the beating of our heart, or the secretion of saliva, is attended with some manifestation of energy, and this energy is shown in one or other of two forms, namely, either mechanical labour or heat. These facts will be more clearly understood if it is borne in mind that what is called *energy* in an agent is merely an expression that that agent is capable of doing work, and that the quantity of energy it possesses is measured by the amount of work it can do. An agent or force is said to do work when it produces any change in the condition of bodies; therefore energy is the capacity for producing physical change. This capacity for producing change or energy is of two kinds, namely, *kinetic energy* or the energy of movement, and *potential energy* or that of position. This latter term means various forms of energy,

which are suspended in their action, and which, although they may cause motion, are not in themselves motion. Thus, a coiled watch-spring possesses energy of position or potential energy, and only wants a touch to transform the energy of position into energy of movement, or potential into mechanical energy. Moreover this transformation of potential energy into kinetic, or *vice versâ*, can take place without any part of the energy being lost, and it is further possible to convert the whole of the energy possessed by any body into heat. Thus if a piece of lead be thrown from a high tower to the ground, and if it strike some hard, unyielding substance, the movement of the lead mass is not only arrested, but its kinetic energy is transformed into violent vibratory movements of the lead atoms. As a result of this violent vibration of atoms, heat is produced, and the amount of this is proportional to the kinetic energy of the lead, which again was proportional to its potential energy when in position on the tower. In the human body the ordinary movements of the whole system and of individual organs are constantly being transformed into heat. If we regard, therefore, the food we consume as the direct source of all this heat and the mechanical energy displayed by the body, it is obvious we can obtain by their measurement a fair idea of the nutritive values of various food stuffs. The problem is, however, not of a uniformly simple nature. In the case of the water and mineral salts of the food, their nutritive value is not difficult to ascertain, because they are simple bodies, and do not undergo any very great chemical change in the body. The nutritive value of the proteids, fats, and carbo-hydrates, however, is not so easy to determine, because not only are they complex bodies in themselves, but, moreover, undergo complicated and ill-understood changes within the body; their nutritive value, therefore, cannot be very accurately expressed.

The simplest measure of the potential energy is the amount of heat which can be obtained by complete combustion of the chemical compounds representing the potential energy. The various statements as to the amount of potential energy possessed by various food stuffs and expressed either in terms of heat or work, are based upon the researches and discoveries of Mayer and Joule, that the amount of power or energy which can be obtained from a given weight of matter was connected with and proportional to the heat given out during its combustion. As a standard of measure of heat, we have the "heat unit," or *calorie.* This heat unit, or calorie, is the amount of energy required to raise the temperature of 1 grm. of water 1° C. The heat unit corresponds to 425·5 units of work, which are

gramme-metres; that is, the same energy required to heat 1 grm. of water 1° C. would raise a weight of 425·5 grms. to the height of 1 metre; or a weight of 425·5 grms., if allowed to fall from a height of 1 metre, would by its concussion produce as much heat as would raise the temperature of 1 grm. of water 1° C.

According to the English system the heat unit is the amount of energy required to raise the temperature of a pound of water 1° F., and will if manifested as a mechanical force, raise 772 lbs. a foot high, or, what amounts to the same thing, 1 lb. 772 feet high. Thus the dynamic or mechanical equivalent of one degree of heat on the Fahrenheit scale is said to be 772 foot-pounds. Adopting the Centigrade scale, then the mechanical equivalent of 1° C., or 1°·8 F., will be 1389 foot-pounds; that is, the energy which will raise the temperature of 1 lb. of water 1° C., or 1°·8 F., will be capable, as a motive power, of raising 1 lb. in weight 1389 feet high. In England the amount of work done is commonly expressed as foot-tons or tons lifted 1 foot; while in France it is often expressed as kilogrammetres or kilogrammes lifted one metre.

Units of work, expressed according to the continental system as gramme-metres, can be converted into foot-pounds by multiplying them by ·007233 and into foot-tons by dividing by 311,000. Similarly kilogrammetres are converted into foot-pounds by multiplying by 7·233, and into foot-tons by dividing by 311.

Applying this principle that as heat production is related to the amount of chemical action ensuing, so likewise is mechanical power production, we find that as a measure of the utility of food, the value of the various food principles as mechanical power producers will correspond with their value as heat producers. Those food principles, which by oxidation give rise to the greatest amount of heat, will, of course, theoretically have the greatest capacity for the production of working power; that is, will possess the greatest potential energy. This theoretical potential energy is not only different in the case of each class of food stuff, such as proteid, fat and carbo-hydrate, but differs also in different foods of each of these classes. In the case of many food stuffs, their actual value in respect of capacity for heat production has been determined experimentally and expressed in relation to the performance of work. Taking the above-mentioned estimate of the mechanical equivalent of heat as the basis of calculation, the following table has been constructed, showing both the units of heat and energy developed by one ounce and one gramme of various substances when fully oxidized, the heat units and energy being expressed according to both the English and metric systems respectively :—

Substance.	One ounce (dried) yields		One gramme (dried) yields	
	English Heat units.	Energy as Foot-tons.	Metric Heat units.	Energy as Kilo-grammetres.
Alcohol (fluid ounces)	786	271	6980	2966
Arrowroot . . .	438	151	3912	1657
Bacon	997	344	8847	3760
Barley meal . . .	417	144	3703	1574
Barley (pearl) . . .	414	143	3678	1563
Beef, fat	1017	351	9069	3841
Beef, lean	572	197	5103	2161
Biscuit	417	144	3703	1574
Bread (wheaten) . .	490	169	4351	1849
Butter	815	281	7264	3077
Cabbage	417	144	3703	1574
Carrots.	310	107	2752	1169
Casein	658	227	5855	2488
Cheese	687	237	6095	2590
Dextrose	443	153	3939	1674
Eggs	745	257	6610	2809
Fish (white) . . .	553	191	4912	2087
Gelatine	618	213	5493	2334
Glutin	690	238	6141	2610
Horse-flesh . . .	542	187	4809	2043
Liebig's Extract . .	495	171	4400	1870
Macaroni	411	142	3652	1552
Maltose	467	161	4163	1769
Milk (cows) . . .	644	222	5733	2436
Milk (human) . . .	545	188	4837	2055
Oatmeal	443	153	3935	1672
Peas	551	190	4889	2077
Potatoes	475	164	4234	1799
Rice	540	186	4806	2042
Starch (wheat) . .	504	174	4479	1903
Sugar (cane) . . .	374	129	3348	1418
Sugar (grape) . . .	368	127	3277	1388

The above figures refer, of course, to laboratory experiments, involving a complete combustion of the particular food stuff, but in the body it is practically only the fats and carbohydrates which are completely burnt; while the proteids are not metabolized beyond the stage of urea, which we know escapes in the urine. If, therefore, we wish to express the available potential energy of the proteid foods, we must subtract the unused potential energy of urea. A given quantity of proteid gives rise to about one-third of its weight of urea, and one ounce of urea yields 85·4 foot-tons of energy; therefore the true available potential energy from one ounce of a proteid food, such as dried beef lean, will be 197 less 28·46 or 168·5 foot-tons. (Danilewski.)

From what has been said, it is evident that it is difficult to compare rightly the potential energy available by the burning of a food stuff outside the body with that which is obtained as the result of combustion within the body, and in attempting to estimate the nutritive values therefrom, allowance must be made for the different degrees of digestibility, the effects of cooking, and even the actual bulk taken. In the case of fats, their nutritive value seems to depend largely on their digestibility, while of the carbohydrates there is little reason to think that starch, grape sugar, or cane sugar differ much in their nutritive value, though Lawes and Gilbert's experiments indicate that cane sugar is more fattening than starch. Among the proteids, we know that gelatine and chondrin have a lower nutritive value than the ordinary proteids, and that vegetable proteids are as nourishing as the animal.

To foods which, when burnt, yield the same number of heat units, the term *isodynamic* has been applied, as expressing in terms of energy their equivalence to each other; that is to say, that so much proteid is isodynamic with so much fat or carbohydrate. Rubner has calculated that 100 parts of fat during combustion, whether within or without the body, yield as much heat as 213 parts of albumin, as 232 parts of starch, 234 parts of cane sugar, and 256 parts of dextrine. These, however, are scarcely practically useful values, since, as we have already learnt, the several nutritive substances are not perfect substitutes for each other. Some German authorities, notably König and Emmerling, have endeavoured to obtain a nutritive value of the food stuffs as based on their market price ratios. Using the term "nutrient unit" as representing a mere national economic standard, they say that—

1 part of carbohydrate has the value of 1 nutrient unit.
1 part of fat has the value of 3 nutrient units.
1 part of albumin has the value of 5 nutrient units. (Lehmann.)

The above estimates are probably true for the conditions of German life, but cannot be accepted as applying absolutely for these islands.

With regard to mechanical labour and the amount of energy expended by the body, it is considered that 300 foot-tons or 100,000 kilogrammetres of external work over and above what is done by the functional activity of the body itself is a good day's work. With regard to heat produced in and by the body no accurate knowledge is available; but the ratio between the amount of mechanical labour done and heat expended by an adult during an ordinary day's work is about one-sixth mechanical labour to five-sixths heat.

Of the total energy developed by oxidation of the food in the body, it has been estimated by Helmholtz that the animal economy is capable of turning only one-seventh to the account of external work, after allowing for the internal work of the body. The late Professor de Chaumont reckoned the internal work to be equal to about 2800 foot-tons daily, and, according to him, to get an ordinary day's work done (say 300 foot-tons) we require five times that amount of energy (1500) in addition to the quantity needed for the body's internal work; or 1500 *plus* 2800 = 4300 foot-tons to be provided from the material taken in as food. For a harder day's work, say 450 foot-tons, we need 2550, that is, five times the first 300 and seven times the next 150, in addition to the internal work, or 2550 *plus* 2800 = 5350 foot-tons. The following estimates have been made as to man's work:—

Light work,	from	150 to 200	foot tons	each day.
Average	,,	300 ,, 350	,,	,,
Hard	,,	450 ,, 500	,,	,,
Laborious	,,	500 ,, 600	,,	,,

Diets.—So far, we have discussed the nature, uses and nutritive values of the food stuffs individually; it is necessary now to briefly discuss them collectively in reference to their powers of maintaining life—whether any one of them alone is capable of supporting vitality, or what combinations and what quantity of them experience and experiment teach us are useful in the food of man. There is abundant evidence to prove that no one group of alimentary substances is alone sufficient to sustain life for any length of time, but that a mixed diet is necessary. Such evidence is derived from instinctive proclivities, from considerations of the comparative anatomy of our digestive organs, from experience and experiment. That man cannot live on any one group of the food stuffs is shown by an examination of the needs of the body, as demonstrated by the daily loss by the kidneys, bowels, skin and lungs.

Various experiments by Parkes, Smith, Playfair, Haughton, Fick, and Ranke have shown that an average man gives off 307 grs. of nitrogen and 4700 grs. of carbon daily. If he wishes to keep in health, this daily loss of nitrogen and carbon must be made up by a corresponding intake of those elements with his food. If such a man subsisted only on a carbohydrate food stuff—say, for instance, bread, which contains 116 grs. of carbon and 5·5 grs. of nitrogen in each ounce—he would, in order to obtain the 307 grs. of nitrogen needed by him, have to consume 3·1 lbs. of bread, while at the same time the necessary quantity of carbon is contained in 2·5 lbs. Or, to take the supposititious case of a man wishing to live on beef (representing the proteids),

and having a composition of 60 grs. of carbon and 10·3 grs. of nitrogen in each ounce, he would, in order to obtain his 4700 grs. of carbon, have to eat daily no less than 4·7 lbs. of that substance, while the required 307 grs. of nitrogen are contained in 1·3 lbs. Therefore, to obtain the proper quantity of carbon, he would be consuming a quantity of meat which contains nearly four times the amount of nitrogen actually required.

The general principles of diet may be summed up in the words of de Chaumont: (1) No single nutritive principle, whether nitrogenous or non-nitrogenous, can support life except for a very short time. (2) Life may be supported upon one nitrogenous and one non-nitrogenous principle for a long time, but for a permanency salts would require to be added. Thus proteids and fats, or proteids and starches would support life. (3) For the best forms of diet, both fats and carbohydrates are needed in addition to nitrogenous matter, and in all probability both starch and sugar among them. It would also appear that a due admixture of more than one form of nitrogenous principle is advisable.

Experience teaches us that our requirements as to food vary much with our exposure to different conditions, and that according to the expenditure of our bodies so should the materials be supplied which are best calculated to yield what is wanted. The human body has been compared to a machine, but it differs therefrom in this, that wear is constantly going on independently of any useful work done, which is not the case in a mechanical engine. Determinations as to the quantity of food daily required by the body have been obtained by means of extended observations of the diets of classes and communities, and also by estimating the sum of excreted matters, which, of course, must be compensated by a suitable supply of food.

From the researches of Playfair, Smith, and others, the usual range, in the diet of an adult man, of nitrogen is daily from 250 to 350 grs. The extremes being 180 grs. in a minimum or sustenance diet to 500 grs. taken during very great exertion. Of carbon, the daily need seems to be from 3500 to 6500 grs. Smith's observations show from 135 grs. of nitrogen and 3270 grs. of carbon in the diet of London needlewomen, to 350 grs. of nitrogen and 6200 grs. of carbon in that of railway navvies. The diets in English convict prisons show the nitrogen and carbon to vary from 226 and 4356 grs. in the light-labour diets, to 263 and 5013 grs. in the hard-labour.

The carbon seems to vary from 3600 to 5800 grs. in diets generally. Weston, while walking 50 miles a day on the flat, and doing something like 790 foot-tons of external work,

consumed daily on an average 545 grs. of nitrogen and 7880 grs. of carbon, or just about twice the amount of each which will support ordinary work. The experiments of Parkes and Pettenkofer upon men to a great extent confirm the conclusions as to the daily needs of man as drawn from a study of class diets. The amounts of carbon and nitrogen taken daily in food are of the highest importance, since these are the chief elements which undergo metabolism in the body. The following table shows the quantity of carbon, nitrogen, etc., in each ounce of the various dried food stuffs :—

One ounce (dried).	Nitrogen.	Carbon.	Hydrogen.	Sulphur.
Proteids . . .	70 grains.	212 grains.	8 grains.	6 grains.
Fat	—	336 ,,	48 ,,	—
Carbohydrates :—				
1. Starch . .	—	194 ,,	—	—
2. Cane sugar.	—	184 ,,	—	—
3. Grape sugar	—	175 ,,	—	—
4. Milk sugar.	—	175 ,,	—	—

The total carbon in an ounce of proteid is 233 grs., but of this 30 grs. are only metabolized as far as urea, and oxidized as carbon monoxide ; making allowance for this, we have a nett total equal to 212 grains of carbon fully oxidized from each ounce of dry proteid.

Assuming these compositions in terms of nitrogen and carbon of the various food stuffs, and accepting that the daily need of an average adult man to keep in health is equal to 307 grains of nitrogen and 4700 grains of carbon, certain *standard diets* have been compiled. Adopting an average of the statements of various authorities, the following amounts express the standard diet for an adult weighing 150 lbs., in terms of dry or water-free food stuffs.

Kind of Work.	Proteids.	Fats.	Carbo-hydrates.	Salts.	Such Diet equalling—		
					Nitrogen.	Carbon.	Potential Energy.
	Ozs.	Ozs.	Ozs.	Ozs.	Grs.	Grs.	Foot-tons.
Rest . . .	2·50	1·00	12·00	0·50	175	3150	2370
Ordinary work	4·50	2·90	14·26	1·06	320	4700	4000
Hard work .	6·00	3·50	16·00	1·50	420	5488	4441

These amounts are, of course, theoretical standards, and, as such, only approximate. The need of so great an increase in the

proteids during hard work is doubtful, while, on the other hand, the need of carbon under the same conditions is possibly greater than given in the above table. As already stated, all the ingredients are reckoned as being quite free from water, but would in actual practice be combined with quite their own weight of water, making the total weight of solid food taken to be from 40 to 20 ounces. In addition, too, some 60 to 80 fluid ounces of water would be taken as drink. As a general rule, it may be accepted that a man consumes daily about $\frac{1}{100}$ of his own weight of dry food, and some $\frac{3}{100}$ of water, or, in other words, each pound of his body weight receives in twenty-four hours 0·15 oz. dry food and 0·5 oz. of water.

It will be readily understood that, though the above-named amounts are accepted as standards, in actual life there are very great individual differences in diets, and that no single standard will meet all cases, because no two men eat exactly the same. The chief influences which affect the amount of food and drink taken are sex, age, work, and climate.

As regards *sex*, women are said to require 10 per cent. less than men; while in reference to *age*, during young life nitrogenous and fatty food are particularly needful to provide for the growth of tissues; in old age, proportionate reductions are demanded, as there is not only lessened labour but actually lessened body metabolism or tissue change. If people are doing great *work*, there is a natural need of more food, especially for proteids and fats; also in a less degree for water. The influence of *climate* on diet is not very defined. In cold countries more fat is consumed than in hot, but how far this increase is due to greater need for energy and body warmth or increased exertion is not quite clear.

In all good and well-considered diets there is a definite proportion between the nitrogenous and non-nitrogenous food stuffs—usually in the ratio of 1 to $3\frac{1}{2}$ or $4\frac{1}{2}$; and the nitrogen should be to the carbon as 1 is to 15. The ratio between fats and carbohydrates which should be aimed at in all diets is roughly as 1 is to 9, but for economical reasons the proportion varies constantly in different practical dietaries.

Having, therefore, an established series of dietetic standards and a knowledge of the chief points to which attention must be directed in regard to food, it is important to be able to examine any given diet in the light of these facts, and be able as well to construct a dietary. To do this, however, it is necessary to have some knowledge of the mean composition of the various articles of diet. The following table, constructed from various sources, shows the percentage composition of the more ordinary articles of food:—

	In 100 parts—				
	Water.	Proteids.	Fats.	Carbo-hydrates.	Salts.
Arrowroot	15·40	0·80	—	83·5	0·30
Bacon (Letheby)	15·00	9·00	73·00	—	3·00
Barley meal (de Chaumont)	11·30	12·70	2·00	71·00	3·00
Barley pearl (Church)	14·70	7·40	1·10	75·80	1·00
Beef, best quality (König)	72·00	21·00	6·00	—	1·00
Beef as supplied to army	75·00	15·00	8·40	—	1·60
Beef, salted	49·10	29·60	0·20	—	21·10
Beef, corned or Chicago (Parkes)	52·20	23·30	14·00	—	4·00
Beetroot (König)	87·00	1·50	—	10·50	1·00
Biscuits	8·00	15·60	1·30	73·40	1·70
Bread (Rubner)	39·50	8·00	1·00	50·00	1·50
Bread, average wheaten	40·00	8·00	1·50	49·20	1·30
Butter, English fresh (Bell)	12·00	2·00	85·00	—	1·00
Butter, very best (Bell)	8·00	1·00	90·00	—	1·00
Butter, salt (Bell)	17·00	—	80·00	—	3·00
Butter, highly salted (Bell)	17·00	1·00	74·00	—	8·00
Cabbage (König)	89·00	2·00	2·00	5·50	1·50
Cabbage, Brussels sprouts	85·50	5·00	0·50	7·80	1·20
Carrots (König)	87·80	1·00	0·20	10·00	1·00
Cheese, Dutch (Bell)	41·00	28·00	23·00	1·00	7·00
Cheese, Single Gloster	36·00	31·00	28·50	—	4·50
Cheese, poor quality (Bell)	48·00	32·00	9·00	7·00	4·00
Cream (Letheby)	66·00	2·70	26·70	2·80	1·80
Eel (König)	57·50	12·50	28·50	—	1·50
Eggs	73·50	13·50	11·60	—	1·40
Fish, salmon (König)	76·00	15·00	7·00	—	2·00
Fish, sole (König)	86·00	12·00	0·50	—	1·50
Fish, herrings fresh (König)	80·00	10·00	8·00	—	2·00
Flour, wheaten fine	16·50	13·00	1·50	68·30	0·70
Flour, wheaten average	15·00	11·00	2·00	71·20	0·80
Goose (König)	38·00	16·00	45·50	—	0·50
Horse-flesh (König)	74·30	21·70	2·60	—	1·00
Lentils	12·50	24·80	1·80	58·40	2·50
Macaroni (König)	13·10	9·00	0·30	76·80	0·80
Maize (Pozziali)	13·50	10·00	6·70	64·50	1·40
Margarine	12·03	0·75	82·00	—	5·22
Milk, average cows	86·90	4·70	3·50	4·20	0·70
Milk, Devon preserved (Blyth)	90·35	4·20	1·15	3·50	0·70
Milk, average town	86·00	5·00	4·00	4·30	0·70
Milk, condensed English (Bell)	27·00	12·00	8·40	50·80	2·00
Milk, condensed Swiss, sweetened	25·60	12·30	11·00	48·70	2·40
Milk, condensed Swiss, unsweetened	61·85	11·35	11·25	13·35	2·00
Mutton, ordinary	76·00	18·00	5·00	—	1·00
Oatmeal	15·00	13·00	6·00	63·00	3·00
Parsnips (Parkes)	82·50	1·30	0·70	14·50	1·00
Peas	15·60	22·00	2·00	58·00	2·40
Pork (König)	47·50	16·00	34·00	—	2·50
Potatoes	74·00	1·50	0·20	23·30	1·00
Rice	10·00	5·00	0·10	84·40	0·50
Turnips (König)	91·00	1·00	0·20	6·80	1·00
Veal, lean (König)	78·00	19·00	1·50	—	1·50

Calculation of Diets.—Of course the above figures are merely approximate; but are sufficiently accurate for the calculation of any dietary, the mode of doing which is sufficiently simple as shown by the following example. How much proteid, fat, carbohydrate, and salts are contained in 12 ozs. of average wheaten bread? On referring to the table, we find that every 100 parts of bread contain 40 of water, 8 of proteid, 1·5 of fat, 49·2 of carbohydrate, and 1·3 of salts. By a simple rule of three sum, we find that the 12 ozs. contain 4·8 ozs. of water, 0·96 oz. of proteid, 0·18 oz. of fat, 5·9 ozs. of carbohydrate, and 0·15 oz. of salts.

In a converse way, supposing a diet is required to yield 5 ozs. of proteid, 3 ozs. of fat, 15 ozs. of carbohydrate, and 1 oz. of salt, and it is wanted to know how much bread, salt butter, and Dutch cheese would be needed to supply it:—

The percentage composition of these may be taken to be—

	Proteids.	Fats.	Carbohydrates.	Salts.
Bread . . .	8	1	50	1·5
Salt butter . . .	—	80	—	3·0
Dutch cheese . .	28	23	1	7·0

Calling the bread a, the butter b, and the cheese c, we get the following equations:—

$$(1)\ \frac{8a + 28c}{100} = 5 \text{ (proteid).}$$

$$(2)\ \frac{1a + 80b + 23c}{100} = 3 \text{ (fats).}$$

$$(3)\ \frac{50a + 1c}{100} = 15 \text{ (carbohydrates).}$$

Simplifying these equations, we get the following:—

$$(1)\ 8a + 28c = 500.$$
$$(2)\ 1a + 80b + 23c = 300.$$
$$(3)\ 50a + 1c = 1500.$$

These can be further resolved thus:—

$$(3)\ 50a + 1c = 1500 \times 28 = 1400a + 28c = 42000.$$
$$(1)\ 8a + 28 = 500 \quad = \quad \frac{8a + 28c = 500}{1392a \qquad = 41500}$$
$$a = 29{\cdot}8 \text{ ozs.}$$

If $a = 29{\cdot}8$, then equation 3 becomes—

$$1c = 1500 - 1490.$$
$$c = 10 \text{ ozs.}$$

If $a = 29{\cdot}8$, and $c = 10$, then equation 2 becomes—

$$80b = 300 - 20{\cdot}8 - 230.$$
$$80b = 40{\cdot}2.$$
$$b = 0{\cdot}5 \text{ oz.}$$

The answer being a, that is the bread, = 29·8, or say 30 ounces.
b, ,, ,, butter, = 0·5, or half an ounce.
c, ,, ,, cheese, = 10·0 ounces.

To find the salts, we say—

Since the bread contains 1·5 per cent. $\therefore \frac{29 \cdot 8 \times 1 \cdot 5}{100} = 0 \cdot 447$

,, butter ,, 3 ,, $\therefore \frac{0 \cdot 5 \times 3}{100} = 0 \cdot 015$

,, cheese ,, 7 ,, $\therefore \frac{10 \times 7}{100} = 0 \cdot 700$

The total salts are . . . 1 162

That is, from 30 ozs. of bread, 10 ozs. of Dutch cheese, and ½ oz. of salt butter, we can obtain 5 ozs. of proteid, 3 ozs. of fat, 15 ozs. of carbohydrates, and 1 oz. of salts.

Although such a diet fulfils theoretical requirements, practical experience would soon show that it was insufficiently varied. It is the great diversity which exists as regards the food consumed by the human race in all parts of the world that is the most remarkable feature in the study of dietaries. Some people live upon a wholly vegetable, others on a wholly animal, and others on a mixed diet. It has already been explained how unsuited any single vegetable food, such as bread, or any single animal food, such as meat, is to supply the daily requirements of the body, and how a judicious mingling of the various food stuffs affords the greatest nourishment in the least bulk. The mixed diet may be regarded as that which in Nature's plan is designed for man's sustenance. On this he appears to attain the highest intellectual and physical vigour, and it is this diet which he consumes by general inclination when circumstances allow the inclination to guide him; also it is in conformity with the construction of his teeth and the arrangements of his digestive apparatus in general. However, where custom and habit have given certain races a peculiar suitability for a purely vegetable diet, the arguments in favour of a mixed diet are not sufficiently strong for the reversal of the customs of many ages.

For translating or changing the elements of a diet into terms of food articles, or *vice versâ*, it is important to remember that no mere calculation of the amounts of food stuffs can properly measure the efficiency of any particular diet, but that other conditions must be considered; the chief of these will be relative to hours and arrangements of meals, digestibility of food, and the effects of cooking.

Hours of Eating.—Next to the quantity and quality of food, attention must be given to the method of taking it. Food should be taken with regularity and at proper periods; long intervals between meals are specially hurtful. As a rule, it may be said that the hours of eating meals are the result of custom and of the other trivial conditions peculiar to different classes of society.

The prevailing custom is for these meals to be taken during the day at intervals of about 5 or 6 hours. Observation has shown that an ordinary meal is digested and has passed on from the stomach in about 4 hours' time, and thus, according to the above custom, the stomach is allowed to remain for a short period in a state of rest before it is filled with food again. Whether the largest meal of the day, dinner, should be taken at midday or at sundown is a question mainly to be decided by circumstances. The former hour is found to be more convenient to men doing manual labour, while the latter seems to be best adapted to the wants of the busy man in the upper and middle classes. Provided the evening meal is not taken at too late an hour, and not too large, there is no reason against this arrangement; but it must not be forgotten that the habit of going to bed or to sleep on a full stomach after a meal is particularly injurious. Similarly, a hearty meal should neither follow nor precede violent exertion. In each case, the stomach is unfit for the vigorous discharge of its office. All persons, both rich and poor, should endeavour to take a little food with either a cup of hot tea or coffee in the early morning before going out to work. Such a practice strengthens the body and digestion at a time when its powers are at their lowest, and, too, in malarial countries has a marked influence in keeping off fever.

Digestibility of Food.—Far more important, as an index of its nutritive value, than mere calculations as to how much proteid, fat, etc., a given article of food contains, is the determination of the degree of its digestibility. On this point it may be said that the proteids and fat derived from the animal world are more readily digested than those obtained from vegetables. As to the carbohydrates, no general rule can be laid down beyond that white bread and rice are the most digestible. The table on p. 127 shows the digestibility of some ordinary articles of diet in the stomach as gathered from Beaumont's experiments; but the figures must, however, be only regarded as giving broad differences of digestibility between foods, and in particular cases may be considerably modified, especially if allowance be made for the effects of cooking.

Cooking.—By cooking, our food is rendered more pleasing to the eye, agreeable to the palate, and digestible by the stomach. Apart from its power of removing any obnoxious property in a food by killing any parasites or disease germs existing in it, cooking so alters the texture of a food as to render it more easy of mastication and subsequent reduction to a fluid state by the stomach. Thus a piece of meat before cooking is tough and stringy, but when cooked the muscular fibres are given a firmness

Food.	How cooked.	Length of time in stomach till digested.
Barley	Boiled	2 hours
Beans	,,	2½ ,,
Beef	Roasted	3 ,,
Bread, brown . . .	Baked	4 ,,
,, white . . .	,,	3 ,,
Cabbage	Boiled	2½ ,,
Eggs	Raw	2 ,,
,, ...	Soft boiled	3 ,,
,, ...	Hard boiled	5 ,,
Fish, salmon . . .	Boiled	1½ ,,
,, sole	,,	2 ,,
Ham	,,	3 ,,
Lamb	Broiled	2½ ,,
Macaroni	Boiled	2½ ,,
Milk	Unboiled	2¼ ,,
,, ...	Boiled	2 ,,
Mutton	,,	3 ,,
Peas	,,	2 ,,
Pork	Salted	5 ,,
Potatoes	Boiled or roasted	2½ ,,
Rice	Boiled	1 ,,
Sago	,,	1¾ ,,
Tapioca	,,	2 ,,
Veal	Roasted	4 ,,

from the coagulation of their albumin, and the connective tissue which binds the muscle-fibres together is made into a soft and jelly-like mass. The result of all this is, the meat is rendered less coherent and more digestible, and capable of being broken down by the teeth and the digestive juices. In the same way, cooking makes vegetables and grains softer, loosens their structure, and enables the digestive juices to penetrate into their substance. It also aids digestion by its action of breaking up the starch granules, which exist so largely in vegetables and grains; if not so broken up, starch offers considerable resistance to digestive action. The warmth imparted to food further aids digestion, and exerts a reviving effect on the system.

We may say that there are six common methods of cooking; namely, boiling, stewing, roasting, broiling or grilling, baking and frying.

Boiling.—This may have for its object either the extraction from the food of its nutritive principles or their retention in it. If we wish to extract all the goodness of meat into some surrounding liquid such as water, as when we make a soup or a broth, the article should be finely cut up and placed in cold water. After it

has soaked for some while, heat should be applied slowly; if a broth is to be made, the heat, though constantly applied, is not allowed to reach actual boiling for some time, by which procedure much of the albumin of the meat is extracted before the subsequent greater heat has been able to coagulate it, and, all the natural juices having for the most part flowed out, the meat itself is left in a nearly tasteless state, but not without some nutritive value. In the making of a soup the same procedure is adopted, with this difference, however, that the boiling is kept up somewhat longer, whereby more of the gelatin of the meat is extracted, and the actual meat itself, owing to more complete deprivation of its constituent juices, rendered still more tasteless and less nutritious. Thus treated, the meat yields its essential principles to the surrounding liquid, which gains in flavour and nutritive properties. The essential difference between the broth and the soup being merely one of degree; that is, how much of the goodness of the meat passes out of it into the surrounding liquid. In the making of a broth some of the meat juices, gelatin, and other constituents still remain in the meat, because the albumin is permitted to coagulate before they have all escaped; while in the other case practically nothing remains of the meat but fibrous tissue, all the rest having passed out into the soup. A due appreciation of the difference between a broth and a soup is important, especially the fact that after the making of a broth the meat residue has still considerable nutritive value, whereas after the preparation of a soup the meat residue has none.

If, on the other hand, the object of boiling is not to extract the constituents out of meat, but rather to retain in it all its flavour and nutriment, then it should not be cut up, but left as a large piece, plunged suddenly into hot or nearly boiling water, and quickly brought to the boil. The application of sudden heat in this manner coagulates the albuminous matter on the surface of the meat, closes its pores, makes an impermeable external coat which stops the escape of the juices from the inner and deeper parts. It is on this principle that a boiled leg of mutton is cooked, taking care, in order to complete the cooking, that the boiling is neither too vigorous nor too long continued, but, after the first short period of boil, the water only just allowed to simmer—that is, be barely at the actual boil. If cooked carefully in this way, the central part of such a joint remains juicy and tender. The most usual fault of cooking meat in this manner is allowing the water in which it is boiled to remain at too high a temperature after the first dipping in to coagulate the surface. The actual period of boiling need not and should not last longer than a few minutes; after that the temperature required for the

surrounding water is not greater than 180° F., actual boiling being 212°. It is usual to add salt to the water in boiling a joint such as has been just explained. There are certain reasons for so doing; first, it has a direct coagulating effect upon the surface albumin; second, it slightly raises the boiling point of water; and third, it increases the density of the water, the effect of which is to render less active the oozing out of the meat juices.

The same principles should guide us in boiling a fish, but with this reservation—namely, that fish being relatively fragile as compared with red meat, many kinds would break if suddenly dipped into boiling water. To avoid this, water just below the boiling point must be used, and the whole process of cooking the fish be completed without actually boiling the water at all. The breaking of a fish by the agitation of boiling water not only spoils the look of the fish, but also opens up the flesh, producing outlets for the escape of its juices, and thereby losing some of its nutritive elements, besides spoiling its flavour. One of the most prevalent errors amongst unscientific cooks is the idea that by boiling is meant vigorous bubbling of the water; more good is done, and just as much heat obtained by a very gentle simmer of the water as there is when the saucepan lid is constantly being lifted. The cooking point of meat is a temperature of 180° F., while the boiling point of water is 212° F. The same principle of trying to retain the soluble and diffusible constituents of a food is involved when potatoes are boiled in their skins; but in the case of a vegetable like the potato, we retain its constituents within it, not by coagulating any surface albumin, because there is none, but by boiling them in their skins or jackets. Over 50 per cent. of the saline constituents of the potato is potash, and potash is an important constituent of blood, hence the great importance of not allowing the waste of the potash from the potato by allowing it to be largely dissolved out of it during the act of cooking by boiling after peeling. It will readily be seen that this loss of potash does not occur when potatoes are cooked in such a manner as to be eaten with their own juice (broth) as in Irish stew, in which case their previous peeling does no harm. Steamed potatoes possibly lose less potash juice than when boiled. Speaking generally, boiled food is less tasty, but more digestible than when cooked in any other way.

It will be convenient here to discuss another cooking method, namely, *stewing*, because it is commonly regarded as a mere modification of boiling; this is only partially true, because they are essentially opposite processes. If the reader has understood what has been written above upon the boiling of a leg of mutton, he will see that its object is to so raise the temperature of the

meat, using water as the medium by which the heat is conveyed to the meat, that it shall as nearly as possible retain all its juices. Now, in stewing, this is largely reversed, because the water is used not only as a heat giver, but also as a solvent for extracting from the meat more or less of its juices. Much of this extraction of meat juice in stewing is more accurately expressed as an act of diffusion rather than of solution, capable of being best secured at high temperatures than low; but experiment teaches us that albumin, which so largely constitutes the diffusible juice of meat, coagulates and gets hard and tough if long exposed to a heat anything near the boiling point of water; hence the need, if stewing is to be properly done, and the meat not rendered so tough, curled and hard as to be more or less uneatable, that the process of stewing should be performed at a temperature of 180° F. or so. This can be readily done if a *bain-marie* or water bath be used. The ordinary carpenter's glue-pot is a familiar form of water bath, being simply a vessel immersed in an outer vessel of water. The water in the outer vessel may boil, but that in the inner one never does, because evaporation from its surface keeps its temperature lower than that of the water from which it gets its heat. All well-equipped kitchens have these double vessels, and every ironmonger sells them; but in the absence of such a double saucepan, every housewife can readily improvise one by performing the stewing in an earthenware jar or glass placed within an ordinary saucepan containing water. It is the more general appreciation of the value and use of the water-bath mode of stewing by French men and women that makes their average cooking so much higher than that of the average English man or woman. English people are apt to speak with contempt of the stewed beef of the Frenchman, forgetting the fact that he never eats it alone, but always associated with a soup or *potage*, which really contains the juices of the beef; and the two dishes combined constitute identical and quite as nutritious articles of diet as the British joint.

Hashing is the same process as stewing, only the meat has been previously cooked instead of being fresh.

Before dismissing this subject of stewing, a few remarks upon the making of ordinary beef-tea or beef extracts as sold under the names of "extract of meat" and "Bovril" may not be inappropriate, particularly as they afford some points of difference from the juices of an ordinary stew. Beef-tea is made by chopping up lean meat very finely and then macerating it in cold water, and the broth thus obtained heated in order to alter its raw flavour. During this heating, which should not exceed 180° F., or just sufficient to coagulate the albumin and colouring matter, a sort

of scum rises to the surface; much of this is fat, and is rightly removed, but if the heating is carried too high some of the other nutritious elements coagulate on the surface, and get removed instead of being left behind. If well prepared, beef-tea is a highly nutritive and restorative liquid, with an agreeable, rich, meaty flavour. If badly prepared, by being subjected to prolonged boiling, beef-tea is merely a solution of the non-coaguable saline constituents of meat—namely, bodies known as kreatin, kreatinine, lactic acid and phosphates. These are all most excellent, but to be regarded as rather stimulants than as nutrients. This explains why in some states of prostration, during illness, when the blood is insufficiently supplied with these flesh juices, the administration of beef-tea, beef extracts, and such-like preparations does much good; but the danger lies in their being regarded as foods suitable for the normal sustenance of the body. This they are not, and, from the very nature of their composition, wanting largely of the nutritious constituents of meat, they never can be.

Roasting.—Just as stewing may be regarded as the national method of cooking on the Continent, so may roasting be regarded as our national method of flesh cooking. Roast meat is usually thought to be more savoury but less digestible than when either boiled or stewed, while, too, the loss is greater, but the same principle underlies it, namely, the retention of the nutritive juices by the formation of a coagulated layer on the surface. In roasting, the juices of the meat are retained (with the exception of those which escape as gravy on the dish), while in stewing, they go more or less completely into the water. In stewing, the heat is communicated to the meat by convection or actual contact; in roasting, the heat is nearly all dry heat radiated to the surface of the joint from the fire. The high temperature rapidly given by radiation to the meat surface forms a thin crust of hardened and half-carbonized albumin; this prevents the evaporation of the meat moisture, sets up a certain amount of pressure inside the joint resulting in the gradual loosening of the fibres and raising of the deeper parts of the flesh to the cooking temperature of about 180° F. In all roasting processes, to hasten its course and prevent burning of the superficial parts, the joint is *basted* or kept constantly enveloped in a varnish of hot melted fat, which, while assisting in the communication of heat, checks the undue evaporation of the juices, or in other words, during roasting heat convection is established by the medium of a fat bath, while in stewing or boiling it is supplied by a water bath. This mode of cooking in a fat bath is applicable not only to ordinary joints but to fish, which, in the form of fillets of plaice or skate,

supplemented by roasting in bacon fat and garnished with some previously well-boiled haricots, constitute both a savoury, cheap and nutritious meal for any poor man.

Broiling or *grilling* is the same in principle as roasting, but the scorching of the surface is greater owing to the larger surface exposed to heat. Baking is analogous, except that the operation is carried on in a confined space, such as an oven. Owing to the confined space and want of ventilation in the chamber or oven in which baking is carried on, the condensed vapour from the article being cooked and the fatty acids, if it be meat, are prevented from escaping, rendering the food so cooked richer and stronger for the stomach. For these reasons, baked food is unsuitable for the sick and delicate.

Frying, speaking generally, is a bad way of cooking, as owing to the heat being applied through the medium of fat, the article so cooked is penetrated with oily matter and often indigestible. In frying, the heat is applied usually much above that of boiling water, as the medium fat can be heated much above 212° F.; and it is probably largely to the difference of temperature to which fish is subjected in the two processes that causes the difference between a boiled sole or mackerel and a fried one. Over and above this, their difference may be due to the fact that the flavouring juices are retained in the flesh of the fried fish, while more or less of them escape into the water when boiled.

It is needless, perhaps, to say that all things used in cooking should be scrupulously clean and carefully cleansed with boiling water after each time of use.

Diseases attributable to Food.—That evils may arise from the indigestibility and bad cooking of food has already been alluded to. There remain for consideration certain bad effects which may arise from either defects as to quantity or quality. The alterations in quantity of food may be either in the direction of excess or deficiency. *An excess of food*, due to too large or too frequent meals, usually leads to an accumulation in the bowels resulting in dyspepsia, constipation, or even irritative diarrhœa. The excess of food may in some cases be absorbed, but more usually large quantities pass away by the bowel absolutely undigested. Any excessive consumption of proteids, especially if unaccompanied by a proportionate increase of exercise, usually results in enlargement of the liver with more or less dyspepsia, diarrhœa or even gout, the urine containing an excess of urea, uric acid and even albumin. An excessive consumption of proteids with a proportionate reduction of fats and carbohydrates was the basis of so-called "Banting;" it being an attempt to reduce accumulation of fat in the body by virtue of the

well-recognized power which proteids have of favouring a rapid disintegration of tissue. Though physiologically sound, banting is unsuited for indiscriminate use as a means to reduce corpulency. An excess of fats or carbohydrates tends to produce stoutness more or less associated with acidity and flatulency, and if continued long, to degenerative changes in the muscles.

In infants and very young children, an excess of starch or other farinaceous food is conducive to the establishment of the disease known as "rickets."

But little is known of the effects of any excess of mineral salts. Common salt taken in excess increases the change of proteid in the body; while an excess of potash salts in the food leads to an increased excretion of sodium chloride. An excess of water with the food means more urine passed, and also increased tissue activity.

Deficiency of food, if protracted, means, of course, a wasting of the tissues as shown by loss of flesh, poorness of blood, followed by physical and mental weakness, and if the loss reach 40 per cent. of the normal weight of the body—death. The more or less complete deprivation of proteids gradually leads to loss of muscular strength, mental debility, fever, and eventually a degree of prostration which may end in loss of life. A deficiency of fats, even if carbohydrates be given, invariably leads to a lowered state of health. A deficiency or even complete withdrawal of carbohydrates can be borne a long time if fats be given, but a deprivation or deficiency of both fats and carbohydrates, although proteids are supplied, soon leads to illness. A deficiency of proteids and fats, especially the latter, is the chief characteristic of the dietaries of communities, notably of armies, public institutions, and the poorer classes in general. Any marked diminution in the amount of water taken as food leads to deficient tissue activity, giving rise to undue retention or storage of water in the body, especially in the muscles, with the establishment of defective health and disease-resisting power.

Associated with defects in the supply of mineral salts is an important diseased state known as "scurvy." Up to within recent years, a view was very generally held that the peculiar disease of childhood known as rickets, characterized by irregular and imperfect ossification of the bones, was due to a deficiency of lime, phosphates, and other salts in the food. In the present day, the real cause is usually regarded as being rather due to the giving of starchy food in excess to infants and children at a time of life when their organs cannot digest it. In scurvy, which is a disease formerly very prevalent in the Royal Navy and mercantile marine, the essential feature is a profound change in the blood,

the result being not only effusions of blood into the tissues, but also a condition of great anæmia and prostration. There is much evidence to show that the change of blood in scurvy is due to the deficiency in the food of the salts of the organic acids such as citric, tartaric, malic, lactic and acetic acids. These salts, as already mentioned, are peculiarly capable by their oxidation in the blood to form alkaline carbonates, with power to preserve the alkalinity of the blood. Thus citric acid and citrate of potash which are the principal constituents of lime juice and other preventives of scurvy, are oxidized into carbonic acid and alkaline carbonates of potassium. In a similar way, fresh meat may be antiscorbutic because it contains an appreciable quantity of sarcolactic acid.

The evils or diseased states which are the result of defects in the quality of food are not only many but so diverse, that it will be more convenient to discuss them under the headings of the different articles of food which immediately follow.

Meat.—Although in different parts of the world, the flesh of various kinds of animals is eaten as meat, that chiefly used is beef from the ox, veal from the calf, mutton from the sheep or goat, and pork from the pig. To these may be added the flesh of fishes. As an article of diet, meat furnishes proteid, fat, and salts. A general analysis of meat yields roughly in a hundred parts 75 of water, 20 of proteid and 5 of fat. The proteid is for the most part, myosin, which exists in the muscle fibres. This myosin is, strictly speaking, a globulin, soluble only in saline solutions or dilute acids and alkalies. It is the result of the coagulation of the muscle after death, this coagulation constituting the so-called *rigor mortis;* in this state meat is tough, but when the *rigor mortis* has passed off, the meat becomes tender. The coagulation of the myosin is due to the presence of sarcolactic acid. Besides myosin, meat contains other proteids such as small quantities of alkali and serum albumin, also a globulin from blood. Of the total proteids in ordinary meat some 13 per cent. are made use of in the body, and possibly even more in the best samples. The amount of fat in meat of course varies, it usually solidifies after death, and in bacon consists chiefly of oleates, in beef of palmitates, in mutton of stearates; these respective kinds of fats being soft and fusible in the order named. It is from these animal fats that margarine is made. In good ox flesh about $\frac{1}{3}$ is fat, in pigs about $\frac{1}{2}$; in thin or badly fed animals, the fat may be as low as 1 per cent. of the meat.

The mineral salts of meat are chiefly phosphate of potassium with small quantities of magnesium, lime and chloride of sodium. Besides these, meat yields certain nitrogenous crystalline bodies,

called commonly *extractives*. These are derived from the changes in the proteid of muscle, and constitute the stimulating principles of beef-tea and broth. The chief extractives of meat are kreatin, kreatinine, xanthine, taurine, sarkine and urea. In estimating the dietetic value of meat some allowance must always be made for bone, which, as usually sold, equals at least $\frac{1}{5}$ of the whole, but this is a much less variable item than the fat.

Constituting as it does so large a proportion of the food of man, a proper inspection of meat intended for food is of the first importance, especially with a view to the detection of whether it be fresh and free from putrefactive changes, and too, whether it be wholesome and sound, and not derived from a diseased animal. It is rare for any one to have opportunities of examining the live stock intended for meat before slaughter. Should such occur it is important to remember that the signs of a healthy animal are, being well nourished, able to rise without difficulty and to walk without lameness. Its coat should be bright and glossy, and free from scabs, boils or sores. The eye of the animal should be bright, with mouth and nostrils moist yet free from discharge. The breathing should be quiet and easy, and the breath free from odour.

Inspection of Meat.—Good and healthy butcher's meat is firm and elastic to the touch, moist but not wet; if well fed, marbled in appearance, from small layers of fat between the muscle fibres. Except in the case of veal and pork, good meat is of a bright red colour. On standing awhile, a red juice oozes out; this should be faintly acid. There should be a fresh but not unpleasant smell. The fat should be firm and whitish yellow in colour and free from blood stains. If putrefaction has occurred, the meat is soft, pale, and usually offensive; if a knife or skewer be thrust into such meat and rapidly withdrawn, it will smell offensively. The juice, too, is usually alkaline, and fails to redden blue litmus paper. Occasionally horseflesh is offered for sale in place of beef. Owing to the bones of the horse and ox differing so much one from the other, horseflesh is usually boned before being offered for sale as beef. It is also more oily than beef, and moreover coarser and darker, without the fat layers in the muscle; it has, besides, a characteristic odour. At times, peculiarities of fodder or pasture may give a disagreeable odour to meat, but it is exceptionally rare for any distinct ill effects to result from eating such. Similarly, the meat from animals recently physicked may be less palatable, and is of course proportionately deteriorated in quality. At other times meat may be coarse, tough, and stringy especially if the animal be aged; such meat should not be regarded as unfit for food simply on account of age. A cow may be slaughtered as late as twenty years

of age, though in such a case the carcase would be extremely thin. The best beef is from oxen of from five to six years of age. As sheep are not used for milking in this country, aged ewes are rarely seen in the meat markets; old rams, however, are by no means uncommon, yielding, of course, poor mutton. Ram mutton is coarse, and often emits an unpleasant smell.

Diseased Conditions of Meat.—The flesh of over-driven animals is said to be injurious, but perhaps the most important question in regard to the wholesomeness or otherwise of meat is how far it is affected by any disease of the animal.

The following are the chief diseases met with or likely to occur in either home-bred or imported animals, and which may be regarded as more or less rendering their flesh unfit for man's food :—

In oxen and sheep	Cattle plague.	
	Pleuro-pneumonia.	
	Anthrax	Boils.
		Black quarter.
		Splenic fever.
	Sheep pox.	
	Consumption (tuberculosis).	
	Actinomycosis.	
	Joint-ill or rheumatism.	
	Foot-and-mouth disease.	
	Liver-fluke.	
	Hoof-rot.	
In pigs	Pleuro-pneumonia.	
	Typhoid fever.	
	Anthrax.	
	Foot-and-mouth disease.	
	Consumption (tuberculosis).	
	Quinsy.	
	Cysticerci (measles).	
	Trichinæ.	
In horses . . .	Glanders.	
	Farcy.	

A few of these affections are parasitic diseases in which the meat or flesh is infected with the young of worms so as to render it unfit for the food of man. With regard to the hurtfulness or not of the flesh of animals affected with general diseases, some variety of opinion exists. The general symptoms resulting from the consumption of such meat are mainly vomiting, diarrhœa, fever, and more or less prostration. In the majority of cases of disease, the meat is dark and moist, usually altered in consistency,

and not rarely marked by tastelessness. The precise nature of the poisons which exist in the flesh of animals affected with the above-named diseases is not known, but there is reason to believe that whatever they may be, they are associated with the presence and activity of bacteria. Although there is reason to think that, with few exceptions, these are rendered innocuous by exposure to the temperature of cooking, still this mode of protection is so uncertain that the safest course is to reject for food the flesh of all animals affected with any acute or specific disease.

There is one disease, however, which, owing to its commonness, is deserving of special remark. It is tuberculosis, or consumption, commonly called by butchers "the grapes," or pearl disease. It is common among oxen, less so among pigs and sheep. The disease is marked by the presence of small white tumours or pearls. These occur mainly on or near the surface of the lungs and on the inside of the chest walls, but they may also be scattered through the lungs, liver and general parts of the body; this latter condition is very rare. Tuberculosis is now known to be associated with, and believed to be caused by, a minute organism called the tubercle bacillus, which is readily carried from one part of the body to another, and consequently is a disease communicable from one of the lower animals to man. For these reasons, it is generally regarded, that, although tubercle bacilli are but rarely found in flesh or meat, still the chance of their being present either there or in the blood is too probable for us to allow the flesh of a tubercular animal being used as food.

Mention has already been made that the flesh of animals used as meat is frequently affected with parasites. In oxen—that is, in beef—the parasite, present occasionally, is what is called the *Cysticercus bovis*. It consists of a head or scolex of a tapeworm having attached to it a cystic expansion. Meat containing this cysticercus gives rise in man to a tapeworm called the *Tænia mediocanellata*. A detailed account of this parasite and its life history is given on page 295.

In sheep, the chief and most common parasite is the *fluke*, which is a kind of worm, in shape very like a sole fish, only measuring 1 to $1\frac{1}{2}$ inches in length and about $\frac{3}{8}$ inch in width. It infests the liver of sheep and occasionally oxen, giving rise to the disease of sheep called "the rot." As cooking always kills the fluke, few cases of disease from this parasite are known in man; but as its presence in a sheep's liver usually causes the animal to be in bad health, the flesh of "rotted" sheep must, as a rule, be regarded as unsound and unfitted for food. Occasionally, both oxen and sheep are affected with the cyst form or cysticercus of the *Tænia echinococcus*, which is a tapeworm whose adult form only affects

dogs and wolves. In man, this cyst gives rise to echinococcus or hydatid disease. A more detailed account of this parasite is given on page 296.

The presence of cysticerci in meat is generally visible to the naked eye; they are so numerous sometimes as to cause the flesh to crackle on section, or even feel gritty; their real nature is readily seen when the meat is placed under a microscope with low power.

The pig is infested with two parasites, both of which exist in the flesh or pork. One is the *Cysticercus cellulosæ*, which, existing in the pig's muscle as a cyst of the size of a pea or small marble, constitutes the affection known as "measles," and this measly pork when eaten gives rise to a tapeworm in man called the *Tænia solium* (see p. 295). The cysticerci of pork are killed by a temperature of 140° F., and if pork were always properly cooked this would render them harmless; but as no dependence can be placed upon the meat being sufficiently heated and cooked, measly pork needs to be always condemned as unfit for food. The other parasite of the pig is the *Trichina spiralis*. This is a very small immature worm, which is found coiled up inside ovoid cysts, which, of the size of $\frac{1}{70}$ inch, lie imbedded in the pig's muscle. When thus affected the pork shows a number of small white specks between the muscle bundles, and is said to be trichinized. As explained on page 293, the eating of this trichinized pork gives rise to the disease called trichinosis in man. Such diseased pork is, of course, unfit for food.

Preservation of Meat.—The chief methods are drying, freezing, salting, the injection of preservative solutions, and the exclusion of air, whether by covering it with an impervious coating or by hermetically sealing in tins. Meat preserved by *drying* is first cut into thin slices, and then exposed to dry air, or to the smoke from a wood fire. In some countries, exposure to a hot sun is sufficient. The employment of extreme cold by *freezing* is now a very common mode of preserving meat, especially during importation from America and Australia. Meat can be preserved in ice for a long time, but unless the freezing had been commenced before rigor mortis set in, such preserved meat rapidly decomposes so soon as thawing is allowed. Experience shows that it is better to keep the meat at a temperature just short of freezing—say, 35° F.

Pickling by means of *salting* is an old and familiar means of preserving meat. During the process, the water of the meat is abstracted, and the salt acts as a preservative. Closely allied to this method is that of *injecting preservative solutions*, such as alum, or even common salt, and also by the application of preservatives

to the surface, notably salt, sugar, boracic acid, salicylic acid and charcoal. The *exclusion of air* is either secured by coating the meat with paraffin, or simply fat, and even by the simple device of plunging the joint into boiling water, so as to form an impervious layer of coagulated albumin on the surface. Probably the most frequent method based on air exclusion is that of hermetically sealing in tin cases. Various devices for securing this have been suggested, the chief being either a complete exclusion of the air by sealing *in vacuo*, or the exclusion of only a part of the air and removal of the oxygen of the remainder by sodic sulphite.

The chief objections to all these methods are, first, the danger depending upon possible original defects in the meat, and, secondly, the risks of decomposition and putrefaction if the preservation have been imperfectly carried out. In the case of tinned meats, not infrequently ill effects have followed their consumption, even when the original material has been above suspicion, and no sign of putrefaction has been present in the tin contents; the only unusual character being the presence of salts of tin, lead or zinc in the meat and jelly, due possibly to the action of variable organic acids upon the solder or tin. Fortunately such events are rare.

As being closely allied to preserved forms of meat, allusion may here be made to the many *extracts of meat* now in the market. Some of them are pure stimulants, and not foods, while others are both. Among the former are Liebig's Extract, ordinary beef-tea and the soups. These are not proteid foods, for besides gelatine they contain only the merest traces of any other proteid; most of the myosin is coagulated during preparation, and left behind in the solid residue. These extracts are really salty foods, containing the sodium chloride from the blood and muscle liquid, the phosphates and potash from the muscle fibre itself, along with the extractives, such as kreatinine. They are essentially stimulants, restoring both mental and bodily activity, but in no sense can be regarded as true nitrogenous foods. On the other hand, there are some preparations which, besides being stimulants, are also proteid foods. These are made by drying more or less completely, partially digested meat, and then mixing this with glutin, starch and concentrated milk. To this class belong such preparations, often given to invalids, as Carnrick's Beef Peptonoids, Darby's Fluid Meat, and others. It is of importance to understand the true value of these preparations, as too often their use is misapplied, owing to a misconception of their real nature.

Fish.—As a class, fish vary much in digestibility, this depending

practically on the amount of fat they contain. The fatter a fish is the more digestible its flesh. Of the fat group of fishes the best are salmon, herring, mackerel, eels and sprats; of the non-fatty, the cod is the most commonly consumed specimen. Of the various shell-fish, oysters eaten raw are almost self-digestive, but lobsters and crabs are not only foul feeders, and as such liable to give rise to ill effects when eaten, but also notoriously indigestible. The same may be said of mussels, these fish in particular being at times extremely liable to cause poisonous symptoms, especially when taken from stagnant water to which sewage has access.

To be at their best and wholesome, fish should be in season. During spawning a fish gets flabby and thin, and during this period is rightly regarded as being "out of season" and unfitted for food. A few fish are peculiar in their breeding, such as brill, dory, lobsters, plaice, prawns, soles, shrimps, turbot and red mullet, which are in season all the year round. Oysters are not in season during the four months spelt without an *r*. The following table gives an approximately correct idea of the seasonableness of the more common kinds of fish other than the foregoing :—

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Bloaters .	in	in	in	out	out	out	out	out	in	in	in	in
Cod . . .	in	in	out	out	out	out	out	out	out	in	in	in
Crabs . .	out	out	out	in	in	in	in	in	in	out	out	out
Eels . .	in	in	out	out	out	in	in	in	in	in	in	in
Haddocks .	in	out	out	out	out	out	out	in	in	in	in	in
Herrings .	out	out	out	out	in	in	in	in	in	in	in	in
Mackerel .	in	in	in	in	in	in	out	out	out	in	in	in
Mussels .	in	in	in	in	out	out	out	out	out	out	out	in
Salmon . .	out	in	in	in	in	in	in	in	out	out	out	out
Shad . .	out	in	in	in	in	in	in	in	out	out	out	out
Scallops .	in	in	in	in	in	in	out	out	out	out	out	out
Smelts . .	in	in	in	in	out	out	out	out	out	in	in	in
Sprats . .	in	in	in	out	out	out	out	out	out	out	in	in
Sturgeon .	out	out	out	in	in	in	in	in	out	out	out	out
Trout . .	out	in	in	in	in	in	in	in	out	out	out	out
Whitebait .	in	in	in	in	in	in	in	in	out	out	out	out
Whitings .	in	in	in	in	out	out	out	out	in	in	in	in

By the Freshwater Fisheries Act, 1878, it is enacted that, subject to special exemption by the Board of Trade for eels, pollen, trout and char in certain fishery districts, from March 15 to June 15 shall be a close time for all fresh-water fish.

As in the case of animals, fish when eaten should be fairly fresh. A fresh fish is firm and stiff; the drooping or not of its

tail is a fair criterion of freshness in a fish. Flat fish keep better than herrings or mackerel. Cod, haddock and whiting keep the best, particularly if rinsed with salt water and stored in a cool place. All fish intended for food should be unbruised, unbroken, and clean. If the scales are dull and damaged it is very suggestive of either ill usage or staleness; softening in places indicates the same. Fish are sometimes affected with a parasite in the form of a cysticercus. This, when eaten, gives rise to a tapeworm called the *Bothriocephalus latus*. These diseased fish are rare in this country, but common in Russia, Poland, Sweden, and Switzerland.

Although the great group of fishes yields a larger number of species used as food by man than either birds or animals, and although there are but few fish in British waters which may not be eaten with advantage, still many prejudices exist with regard to its use. This is much to be regretted, as fish are most valuable and important articles of nourishment; if perhaps not possessing the satisfying and stimulating properties that belong to the flesh of birds and quadrupeds, still the health and vigour of the inhabitants of fishing towns, where fish often forms the only kind of animal food consumed, show that it is capable of maintaining the body under active conditions of life. The fish-eating races and classes are remarkably strong and healthy. For the sick or weakly in whom the powers are too feeble to digest the stronger kinds of animal food, fish possesses valuable properties.

The processes of drying, pickling, salting, and smoking are employed for the preservation of fish. Each process considerably lessens its digestibility, and therefore unsuits it for either the dyspeptic or the invalid.

Eggs.—From the fact that the young chick is developed from it, an egg necessarily contains all that is required for the construction of the body. On this account eggs are often spoken of as typical natural foods. Proteid matter is largely present, under the form of albumin, both in the white and yolk. Fat exists as an oil in the yolk. Carbohydrates exist in the form of minute quantities of a saccharine matter, and water and salts complete the list. The hen's egg usually weighs 2 ozs., but those of ducks and some sea fowl weigh more. The shell of an egg constitutes some 10 per cent. of the total weight; the white, 60 per cent.; and the yolk 30 per cent. The white of egg consists chiefly of albumin, with traces of fat and salt; the yolk consists largely of fat and salts, with a small amount of globulin. Ducks' eggs contain generally more fat than those of hens. Eggs offer a convenient and concentrated article of diet, rich in fat and

proteid, but are at times indigestible, particularly if overcooked. They are conveniently preserved by exclusion of their contents from the air, either by coating the shell with oil, wax, or gum. Their condition as to freshness is readily determined by dissolving 2 ozs. of common salt in a pint of water; in this solution a good egg will sink, while a stale or bad one floats.

Milk.—Milk not only constitutes the chief diet for children up to some eighteen months of age, but also enters very largely into the food of adults. All milk may be regarded as nothing more than an emulsion of fat containing proteids, salts and carbohydrates in solution in water. The average composition of milk per 100 parts, from the chief sources as used by man, is shown in the following table:—

Kind of Milk.	Specific Gravity.	Total Solids.	Proteids.	Fats.	Carbohydrate.	Salts.	Water.
Human . . .	1027	12·60	2·29	3·81	6·20	0·30	87·40
Cow's . . .	1032	12·83	3·55	3·69	4·88	0·71	87·17
Mare's . . .	1035	9·21	2·00	1·20	5·65	0·36	90·79
Ass's . . .	1026	10·40	2·25	1·65	6·00	0·50	89·60
Goat's . . .	1032	14·30	4·30	4·78	4·46	0·75	85·71
Buffalo's. . .	1032	18·60	6·11	7·45	4·17	0·87	81·40

Although all the above are used at times by man for food, the most important kinds undoubtedly are human milk and cow's milk; and these differ from each other in some essential particulars. As seen by the preceding table, while there is more carbohydrate in human milk than in cow's, the reverse is the case with the proteids and salts; the fat being much the same in them both. Ass's milk, except in regard to its fat, is most like human milk, but mare's milk contains even less fat and proteid than the ass's; while, on the other hand, milk from both the goat and buffalo are very rich in fat.

The proteids of milk consist largely of casein; but there is also some albumin, with traces of globulin. The casein probably exists in milk in combination with phosphate of lime, which helps to keep it in solution.

The salts of milk are both numerous and various, being composed really of all the mineral constituents necessary to the growing body.

The fat of milk is nothing more than minute oil globules suspended in the milk, and which, upon standing, rise slowly to the surface, forming cream. One part of cream is said to correspond to 0·2 of fat roughly; the proportion of cream yielded

by a pure milk varies, but may be said to average 10 per cent., being as high as 14 in some cases, and as low as 6 in others. The amount found in a given time is no measure of the richness of the milk; water added to milk causes a more rapid separation of the cream. When milk is subjected to centrifugal action, as in the *separator* so largely used now in commercial dairies, a much larger proportion of cream is obtained than by the mere skimming process. As a result of this, skim milk contains 1 per cent. of fat, while separated milk has practically none.

The carbohydrate of milk is a peculiar sugar, somewhat like cane-sugar, and called lactose, or sugar of milk. This body, like all other sugars, undergoes fermentation under the influence of micro-organisms, and one especially, called the *Bacterium lactis*, abounds in dairies and other places where milk is kept. This micro-organism converts the milk-sugar into lactic acid, while at the same time the proteids are partly decomposed and partly coagulated, the milk itself becoming sour with enclosure of the fat in the coagulated casein. Many other micro-organisms produce coagulation of milk, notably the *Bacillus butyricus* of butyric acid fermentation. Some others have the power of changing the colour of milk, particularly if lactic acid fermentation has occurred. Thus the *Bacillus cyanogenus* causes blue milk; the *Bacillus synxanthum* causes yellow milk; the *Micrococcus prodigiosus* produces red milk; while other bacteria at times cause milk to become ropy and stringy. In nearly all these cases, the milk is apt to cause diarrhœa, and is unsuited for food. Alcoholic fermentation of the milk-sugar can also be set up by certain micro-organisms. "Koumiss" is the result of the alcoholic fermentation of mare's milk, and "Kefir" is that of cow's, goat's and sheep's. After the lactic acid fermentation of milk has set in, the casein gradually decomposes, and, during the early decomposition of the proteids, very frequently highly poisonous compounds are formed, such often being the cause of the violent poisonous effects which at times are produced by ice-creams and other articles of food into the making of which milk enters.

Boiling of milk produces coagulation of the albumin, some obscure changes in the sugar, and greater coalescence of the fat globules. Micro-organisms and ferments are at the same time destroyed, a fact which explains the better keeping qualities of boiled milk. Hot weather tends to hasten fermentation and decomposition in milk.

The actual composition of cow's milk is influenced by not only the breed of the animal, but also by the kind of feeding, and the time of calving and milking. The effect of diet is largely shown by the increase of sugar found in the milk of cows fed

upon fodder rich in carbohydrates, such as carrots and beetroot. The addition of proteid in the diet raises the casein, but not the fat. The colostrum, or milk of cows recently calved, is poor in sugar, but rich in casein and albumin. The first part of a yield during milking, known as fore milk, is deficient in fat, but the latter part, called the strippings, is very rich in cream.

It is well known that in human beings, bitters and purgatives, if taken by the mother, act upon infants taking the milk. Diseased potatoes and turnips in the food of cattle, without actually affecting the goodness of milk, often cause it to smell and taste unpleasantly; other fodders often produce poisonous effects, as in goats feeding upon meadow saffron inducing severe diarrhœa, or in the case of cows affected with "trembles," due to eating the *Rhus toxicodendron*, their milk gives rise to vomiting and constipation. Milk allowed to stand long in warm dirty rooms has a remarkable power of absorbing effluvia, rapidly becoming sour and objectionable, and is a fruitful cause of diarrhœa occurring among the children of the poor.

Milk may be affected by diseased conditions of the cow or the animal yielding it. In foot-and-mouth disease, cow's milk varies very greatly; but a constant feature of such milk is the great excretion of serum albumin. Milk of cows affected with foot-and-mouth disease should never be consumed as food, as it may cause disease in human beings. Tuberculosis in cows undoubtedly affects the milk yielded by them, particularly when the teats are tuberculous, and such milk, if consumed, may lead to the same disease (consumption) in man. There is reason, too, to think that both scarlet-fever, diphtheria and enteric fever, and also cholera, are in many cases propagated by means of milk, the milk becoming infected, either direct from the animal, or by the use of water impregnated with the poison. Since boiling the milk invariably destroys the specific micro-organism associated with these and other diseases, this procedure should be invariably done as one of the most reliable measures against diseases arising from the use of milk.

Preservation of Milk.—Boiling it, and then tightly corking the vessel, is practically the simplest method for the preservation of milk; but, as a rule, this is but temporary. The same end is attained by adding antiseptics, such as salicylic acid, boric acid, or boro-glycerine, to the milk after it has been boiled. The best forms, however, of preserved milk are the concentrated ones, such as the dried milk, or condensed milks with or without sugar. Those without sugar keep less well than those with sugar, once the tin in which they are sold is opened. The majority of condensed milks are made by evaporating down the original milk to

a third or a quarter, and then adding sugar to it; this added sugar tends to make condensed milk rather fattening; but, on the whole, its nutritive value is below that of the fresh article. Strictly speaking, both "Koumiss" and "Kefir," which are fermented milks, are forms of preserved milk, both containing lactic and carbonic acid, with some alcohol. They are not much used except as foods for the sick, in whom digestion is feeble.

Adulterations of Milk.—The chief adulterations of milk are the additions of water and the removal of cream; while carbonate of soda, salt, boracic acid, or salicylic acid, glycerine and starch are added, either to preserve the milk or to mislead the analyst. A common procedure is to remove part of the cream, which would naturally raise the specific gravity, and then, by adding water, to bring the specific gravity down to the normal. The addition of water lowers the specific gravity, the fat, solids not fat and the salts per cent. This added water can be sometimes detected by taking the specific gravity of the milk by means of a lactometer, which should be done at a temperature of 60° F.; if at a higher or lower temperature than this, 1° of specific gravity must be deducted or added for every 10° of heat. In good milk, the specific gravity is from 1028 to 1034; while, in creamed milk, it is from 1033 to 1037; that is to say, it is lowered by watering and increased by skimming. This taking of the specific gravity alone is not to be relied upon as an index of the character of the sample, but should be taken in conjunction with the facts relating to the fats and total solids.

The total solids can be estimated by taking a weighed quantity of milk, and evaporating it slowly to dryness, and re-weighing. Usually 2·5 c.c. of milk are taken for this estimation, and in good milks the total solids should not be less than 12 per cent. The fat in a good milk should not be below 3 per cent.; it is conveniently estimated by mixing a weighed quantity of milk with a weighed amount of burnt gypsum, and evaporating to dryness. The fat is extracted from the residue by ether, and the ether then evaporated, when the residue is again re-dried, re-weighed and calculated out as fat per cent. The amount of fat so determined deducted from the total solids gives the "solids not fat," and as the result of many analyses, these are found, with very rare exceptions, not to fall below 8·5 per cent. Hence this amount is adopted as a standard, and if a given milk sample contains x per cent. of solids not fat, and x be less than 8·5, we are justified in presuming that, however poor the milk may have been to begin with, it must now have added water in it. Thus, presume a given sample of milk has yielded 3·5 per cent. of fat, and 10·5 per cent. of total solids. The solids not fat are

obviously 7 per cent., and working upon the above-mentioned minimum standard of 8·5 for solids not fat, we get the following formula: $\frac{100 \times 7}{8{\cdot}5} = 82{\cdot}35$ parts of original or genuine milk in a 100; or in other words, over 17 per cent. of water may be presumed to have been added to the sample. The ash of a good milk rarely falls below 0·7 per cent., and accepting that as a minimum standard, a similar equation can be stated, if the observed amount of ash be known, as a means of calculating the degree of purity of any particular milk. The ash of milk is of course estimated by incinerating the total solids of a given bulk of milk, weighing and expressing as a percentage.

Sugar in milk is easily determined by first precipitating the casein, by means of acetic acid, from 10 c.c. of milk; filtering, and then diluting the filtrate or whey with distilled water to 100 c.c. This diluted whey contains the lactose or milk-sugar in solution, and is next treated with a solution of copper until all the copper is reduced to red suboxide and no blue colour remains in the liquid. The copper solution is so made that 10 c.c. are decomposed by 0·0667 grms. of lactose.[1] If, say, 15 c.c. of a ten-times diluted whey are required to reduce 10 c.c. of copper solution, then $\frac{15}{10}$, or 1·5 c.c. of the original milk are needed to reduce that amount of copper solution, and 0·0667 grm. lactose $\div$ 1·5 = 0·0445 grm. of lactose in 1 c.c. of milk, or 4·45 per cent.

The presence of added glycerine in milk can usually be detected by the exceptional sweetness of the dried solids.

Butter.—This really is the fat of milk clotted together, and consists chiefly of neutral fats mixed with water and small amounts of casein and salts. Average butter may be said to have the following composition per cent.: Fat, 78 to 94; curd, 1 to 3; water, 5 to 14; salt, 0 to 7. The flavour of a good butter is due to butyric and caproic acids, which constitute about 8 per cent. of the fat, the rest being composed of glycerides of oleic, stearic, and palmitic acids. The water in a good butter should not exceed 16 per cent., an excess lessens the keeping quality of the butter; it contains ordinarily in solution milk-sugar and the milk-salts. Common salt is usually present, but generally added after the butter is made. Artificial colouring matters are often present

[1] Take of pure copper sulphate 34·64 grms., and dissolve in 200 c.c. of distilled water. Take also 173 grms. of the tartrate of sodium and potassium and dissolve in 480 c.c. of caustic-soda solution. Mix these two solutions slowly together, and dilute with distilled water to 1000 c.c. 1 c.c. of this solution is reduced by 5 mgms. of either glucose or inverted sugar; and by 6·67 mgms. of milk-sugar or lactose.

in butter, notably annatto, but it is harmless; occasionally starch is added to give weight, and may be recognized by its blue reaction with iodine. Practically the only adulteration in butter is the substitution of foreign fats such as tallow, lard, palm-oil, rape-seed oil, or cocoa-nut oil, for milk fat; and as a result the analysis of a butter turns mainly upon the properties and composition of the fat.

The amount of fat can be estimated by dissolving it in ether, evaporating the ether solution, drying and weighing. For the detection of an admixture of foreign fats, several methods have been proposed; the principal being: (1) taking the specific gravity of the sample. That of water being unity, a pure butter usually has a specific gravity of ·911 to ·913; an adulterated butter one of ·902 to ·904; and an artificial butter one as low as ·859 to ·861. (2) Determining the melting-point of the fat after separation from the other constituents. The melting-point of pure butter fat is 95° F., but may vary; the addition of animal fats, such as lard, raises the melting-point, while vegetable fats, such as rape-seed oil, tend to lower it. (3) Determination of the fixed fatty acids. This, though rather a difficult process to do, is most generally relied upon. It is based on the fact that when saponified with a caustic alkali such as soda or potash, and then decomposed with hydrochloric acid, the individual fatty acids which go to make up butter are obtained. A certain number of these are soluble in water, and others are not, and it is owing to the insoluble fatty acids obtainable from butter differing in amount from those obtainable from other animal fats that pure butter can be detected from artificial. The figures being, that if the insoluble fatty acids are over 89 per cent. there is an admixture of foreign fat.

Of artificial butters there are several; but in their manufacture they are very similar, consisting really of a certain amount of genuine butter mixed up with animal or vegetable fats such as lard, rapeseed oil, etc. By the law of 1881, all these artificial butters are ordered to be called and sold as *margarine;* in the United States, they are termed oleo-margarine. If made from pure animal fats, these artificial butters have as high a nutritive value as pure butter. Their average melting-point is 86° F., and the insoluble fatty acids contained in them are usually as high as from 92 to 95 per cent., as compared with 88 or 89 per cent. in pure milk butter.

Cheese.—This is made from milk by the action of rennet, which is commonly derived from the fourth stomach of the calf. Cheese consists of coagulated casein, with varying proportions of fat and salts. The different qualities of cheese depend mainly upon whether they are made from pure milk, from skimmed milk,

or from a mixture of skim and whole milk. Thus, Cheddar, double Gloucester, Cheshire and some American cheeses are made from whole milk, while Stilton is made from whole milk to which cream is added. Dutch, Parmesan, Suffolk and Somersetshire cheeses are made from skimmed milk. Cream cheese consists of the fresh curd which has been moderately pressed; it is eaten without being allowed to ripen. When a cheese is kept, it undergoes a change known as "ripening," which is essentially a decomposition, whereby the casein undergoes a fatty change, including the formation of lime salts of the fatty acids and the production of a soluble compound of phosphoric acid with casein, from the phosphate of lime usually present in milk.

As an article of diet, cheese is very useful, being particularly rich in both proteid and fat; the only objection to it being its occasional indigestibility. Its adulterations are unimportant, the chief being starch, to give weight. On an average, the water in cheese ranges from 20 to 35 per cent.; the proteid from 25 to 50 per cent., the fat from 12 to 20 per cent., and the salts some 3 to 6 per cent. Cheeses usually contain small amounts of milk-sugar, lactic, and other organic acids. The richer kinds of cheese are very liable to form the seat of growth of certain animal and vegetable organisms. The maggots or larvæ of a fly (*Piophila casei*) are well known, so also is the cheese mite, or *Acarus domesticus*. The mould on a cheese is composed of minute vegetable organisms of the fungus tribe; the red mould is caused by *Sporendonema casei*, and the blue mould by *Aspergillus glaucus*.

Vegetable Foods.—This large group, which includes a great number of articles of diet, is chiefly remarkable for the fact that although it supplies a certain quantity of proteid and fat, its chief functions are for the provision of carbohydrates, vegetable acids, and salts to the organism. Further, owing to the large amount of water which vegetable foods take up during cooking, they may also be said to supply a large quantity of water to the body. The proteids of vegetables are mainly in the form of globulins and albumoses; the most important of them being *glutin*, which is largely present in wheat-flour. Glutin does not exist as such in wheat-flour, but is formed from the globulin and albumose, naturally present, by the action of water (see page 109). Glutin being readily digested, forms a very valuable proteid food; it can be obtained also from rye-flour, but less easily than from wheat. *Legumin* and *conglutin* are other proteids found chiefly in the Leguminosæ or peas and beans. These proteids are like glutin, derived by the action of water from the globulin and albumose present in the grains. The fats yielded by vegetable

food are very small in quantity, and, from a nutritive point of view, quite unimportant.

The carbohydrates, either as starches, gums (dextrine), or sugars, constitute the chief part of all vegetable foods. In the cereals, potatoes, peas and beans, starch is the chief carbohydrate, coupled with small quantities of sugars or dextrines. In beetroot and sugar-cane, of course, cane-sugar is the carbohydrate, while in the ripe fruits it exists in the form of glucose or grape-sugar. The starches are a large class, and vary as much in the size, form and structure of their grains as they do in their origin, which embraces not only wheat, oats, barley, rye, maize, peas, beans and potatoes, but includes the various forms of arrowroot, tapioca and sago. In its uncooked state, a starch grain is hard and not easily digested; it is composed of two bodies called *granulose* and *erythrogranulose*, enclosed in cellulose coverings. Granulose, which constitutes the greater part of the starch grain, turns blue with iodine, the erythrogranulose turns red with the same, while the cellulose is turned yellow by iodine. Moist heat causes the cellulose coat to burst, so that the grain swells up and the starch is set free. Starch grains have in the majority of cases a sufficiently characteristic appearance, under the microscope, to indicate their origin, and it is upon their peculiarities of size and form that the various adulterations of the starches by other kinds is best detected. Wheat-flour being the most important, is the kind most usually adulterated with other varieties of starch. To examine a starch under the microscope, it is sufficient to moisten a little of it in a state of fine powder with a drop of water or glycerine upon a glass slide. When so examined, they can be conveniently divided according to their appearance into two groups: (1) a group in which their contour is even; this includes wheat, rye, barley, pea, bean, the arrowroots and potato; (2) the other group is one in which, instead of the contour being even, it is marked by facets or surfaces, either completely, as in oats, maize, and rice, or only partially so, as in tapioca and sago. The chief characteristics and appearance of the various starches will be noted in the subsequent figures.

The vegetable foods as a class yield excessive quantities of phosphates and potash as compared with the animal foods which are particularly rich in chlorides and soda; on this account, common salt or chloride of sodium is a special need among vegetable feeders. Iron is usually present in most cereals, particularly in wheat, in which it exists mainly as a phosphate.

Wheat which is grown in this country is a kind known as *Triticum vulgare;* the grain is surrounded by four coats, each of which is composed of special shaped cells. Within these coats

is the grain proper containing the starch, fat, proteid, and salts. The starch grains of wheat (Fig. 28) are very unequal in size, some being very large, and others small; the large ones have a central spot, or hilum, and are marked by faintly concentric rings; the smaller ones are often angular. In the process of milling, the various coats of the wheat grain are more or less removed and separated as bran, the inside of the grain being ground up so as to constitute flour of the best quality. In the second-rate flours, this separation of the bran is less perfectly carried out, the result being a wholemeal flour of a dark colour. Wheat-flour is rich in proteid and carbohydrate, but poor in fat and salts. Its proteid, as already explained, exists as a globulin and an albumose, and from these, by the action of water, glutin is formed. The amount of glutin obtainable from a flour is a test of its quality and suitability for bread making; usually this amount is from 8 to 12 per cent. Its contained water should not exceed 16 per cent.; the more water present, the less the keeping quality of the flour; the salts are chiefly phosphates of potash and magnesia. A good flour should be white in colour and free from mouldy smell or acidity. It is occasionally adulterated by mixture with other starches, notably potato and rice starch, these can be readily recognized with the microscope. Both animal and vegetable parasites occur in flour, and can usually be detected by microscopical examination. The more common animal parasites are the weevil (*Calandra granaria*), the mite (*Acarus farinæ*), and one or more kinds of moth belonging to the micro-lepidoptera. The commonest vegetable parasites of flour are various fungi; one called *Puccinia graminis*, constitutes mildew or red rust of wheat, and whose ripe sporangia show themselves under the microscope as dark-brown club-shaped bodies filled with spores; another parasite is bunt, caused by the *Tilletia caries*, which microscopically appears as round reticulated cells. Another fungus called *Ustilago segetum*, causing smut, is more common in barley or oat-flour than in wheat. Its spores or seeds are smaller than those of bunt, being also circular, nucleated and not reticulated. The chief preparations of flour are bread, biscuits, macaroni and vermicelli.

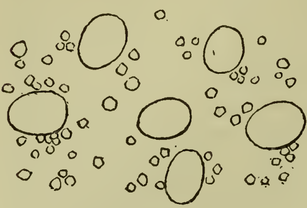


FIG. 28.—Wheat starch.

Bread.—The best bread is made from white wheat-flour, but brown and wholemeal breads are made from flours which contain more or less of the bran or wheat-grain coats. The

disadvantages of wholemeal bread are, first, its dark colour, and next, the irritating and indigestible qualities of the cellulose of the bran. On the other hand, if we take bran as forming 16 parts of the grain, we have an addition to the bread, by inclusion of the bran, of some 0·7 per cent. of proteid and 0·16 per cent. of salts.

Bread is made by mixing flour with water and kneading it so as to form dough by the cohesion of the glutin. To this dough is added a ferment or leaven, usually consisting of a mixture of potato, flour and brewer's yeast. The addition of this leaven gives rise to a ferment action on the starch, whereby alcohol and carbonic acid gas are formed in the dough, resulting in the latter becoming broken up and perforated by innumerable holes. During baking, a certain quantity of sugar and dextrine is formed from the starch, while too, in consequence of the full aeration of the dough, the bread mass becomes light and digestible. In some bakeries, in place of using leaven or yeast, powders consisting of tartaric acid and bicarbonate of soda are added in order to generate the necessary carbonic acid. In another system, known as Dauglish's, the carbonic acid is generated separately by the action of sulphuric acid on marble, and the resulting carbonic acid gas forced into the dough by pressure. It is claimed for these unfermented breads that they have the advantage of containing no alcohol, acetic acid and other bodies, the products of yeast action. This may be the case, but, on the other hand, the action of yeast is largely a digestive one, by which the starch is changed into maltose and dextrine, and some of the proteids into albumoses, or even peptones.

A good bread should be white in colour; any yellowness is suggestive of either an old flour, bad yeast, or a mixture of rye or bran. The acidity of bread should not exceed 0·18 per cent., and the whole loaf should be permeated in every part with small regular holes. Its contained water should not exceed 50 per cent., nor the ash be over 3 per cent. Alum is occasionally added to bread to improve the colour, and check fermentation, any excess over 10 grs. per 4-lb. loaf being regarded as an adulteration. It is roughly detected by pouring upon a slice of bread some freshly made decoction of logwood chips and then a solution of carbonate of ammonia. If pure, the bread is only stained pink; if alum be present, a marked blue to violet colour is produced. The estimation of the precise amount of alum in bread involves a somewhat lengthy process which is beyond the scope of this book. Although bread differs somewhat in composition from flour, its disadvantages as a food are more or less the same, namely, too little fat and too little sodium chloride or salt. In daily life, the deficiency of fat is made up by eating butter, dripping, or bacon

with bread, while in the baking half an ounce of salt is added for each 4 lbs. of dough.

Biscuits.—The ordinary kinds are nothing more than well-baked mixtures of flour and water; though the more fancy varieties contain often milk, butter and eggs. Owing to the absence of yeast in their preparation, biscuits do not contain the products of its action upon the carbohydrates and proteids of flour. Taking weight for weight, biscuits contain more nourishment than bread, but are apt to be indigestible and monotonous if consumed for long.

Macaroni and Vermicelli.—These are both preparations of flour. They are made chiefly from the flours of the hard wheats of France and Italy, which are particularly rich in glutin. They are very valuable foods, being distinctly of higher nutritive value than bread.

Barley very closely resembles wheat in its composition, but differs somewhat in the character of its proteids. These do not on the action of water form glutin, but remain in a soluble form as globulin, albumin and albumose. It is difficult to say how far this affects its nutritive value, but it undoubtedly affects the capability of barley being made into bread, and as such largely used as an article of diet. Its starch grains resemble both in size and appearance those of wheat, but their rings or markings are more distinct. When the whole barley grain is ground, it forms *barley-meal;* when deprived of its husk, and roughly ground, it constitutes *Scotch*, *milled* or *pot barley*.

Pearl barley is the grain deprived of the husk, rounded and polished by rubbing. So-called *patent barley* is merely pearl barley crushed to the state of flour. Barley water is prepared from pearl barley, and forms a slightly nutritive liquid for infants and the sick. *Malt* is the product yielded when barley has been allowed to germinate, and the germination stopped at a certain point by exposure to heat on a kiln. As a result of this process, the starch of the grain is largely converted into sugar, by the development within the barley grain of a peculiar active nitrogenous ferment called diastase. It is from malt that beer is largely made (see page 169). There being little or no glutin in barley, it cannot be made into ordinary bread; when barley bread is made, it is usually from a mixture of barley-meal with wheaten flour. Barley cakes are eaten in some places on the score of economy; but, as compared with those made from wheat, are less palatable and less digestible.

Rye.—Although little used in this country except for malting, rye in the northern countries of Europe is largely used for making bread. In its percentage composition, rye closely resembles wheat, its proteids forming, on the addition of water, a kind of glutin. Rye bread is dark in colour, somewhat heavy and very acid; but falling little short of wheaten bread in nutritive value.

Rye bread is indigestible and apt to cause diarrhœa. If mixed with two parts of wheat-flour, rye-flour makes an excellent bread. The starch grains of rye are very like those of wheat or barley; but, however, have usually a hilum which is star-shaped, while some of the grains are very large in size (Fig. 29). The common rye is a very hardy cereal, and is commonly sown in soils which are too poor to grow wheat. Rye is subject to a very peculiar fungus disease, by which the grain is enlarged and turned black, producing what is known as ergot of rye. The cause of the disease is a fungus called the *Claviceps purpurea*. When the ergot gets mixed with healthy rye, it becomes mingled with the bread and leads to a disease in men called ergotism, the symptoms of which are vomiting, diarrhœa, followed in severe cases by either loss of sensibility, gangrene, or paralysis. This disease is practically unknown in this country, and much less prevalent now than formerly abroad. On account of the excessive size which ergotized rye grains attain, they can be separated by sifting from the unaffected seed: when the grain has been ground into flour, the ergot may be detected either by the microscope or by making of it a paste with an alkali, and then adding nitric acid to excess; on neutralizing, if ergot be present, a violet-red colour is produced.

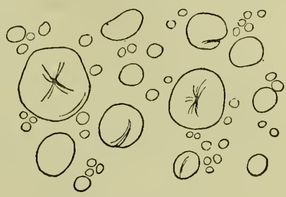


Fig. 29.—Rye starch.

Oats.—As met with in commerce, oats consist of the seeds of the *Avena sativa* enclosed in their husks. When deprived of this integument, the grain goes by the name of *groats* or *grits*, used in making porridge; and these groats, when ground down fine, constitute *oatmeal*, from which gruel is made. Of all the cereals, oats rank next to wheat as articles of food, being noticeable for containing large amounts of proteid and fat—particularly the latter. Oats resemble barley rather than wheat, in that their proteids do not form glutin on the addition of water; on this account oat-meal cannot be vesiculated and made into bread like wheaten flour. It is, however, made into thin cakes by mixing into a paste with water, and then baking on an iron plate. Owing to the large amount of cellulose which they contain, this is apt to irritate the intestines, and more or less interfere with digestion. The grains of oat starch (Fig. 30) are minute and faceted, often tending to collect together into

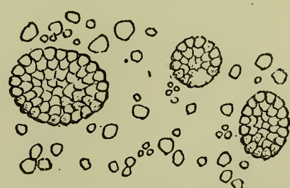


Fig. 30.—Oat starch.

groups or compound grains. In the form of oat-meal, oats can be taken for long periods without distaste, and in this form, constitute a material part of the dietary of the Scotch peasantry.

Rice.—The common rice, or *Oryza sativa*, is extensively cultivated in India, China, West Indies, Central America and in some parts of Southern Europe. Its starch grains (Fig. 31) very closely resemble those of oats. Rice is a peculiar grain food, inasmuch as it is remarkably poor and deficient in proteids, fats and salts. For this reason it needs to be combined with meat, peas, or beans, to supply the proteid with fat, and common salt. It is essentially a carbohydrate food, and, if properly and sufficiently cooked, is very digestible. It is best cooked by thoroughly steaming; if boiled in water, it loses some of its already small quantity of proteid and saline matter. It cannot be made into bread, but is much used in France for mixing with wheaten flour to make the very white bread which is in request in that country.

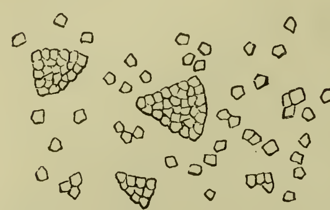


Fig. 31.—Rice starch.

Maize.—Though not much used in England, maize or Indian corn is an important food in America and in Italy, where it is called *polenta*. In its nutritive value, maize resembles oats, containing a large quantity of fat. When made either into cakes or porridge, it affords a valuable food. Maize, being deficient in glutin, does not make good bread; it is, moreover, harsh in flavour. This defect is largely removed by treating it with caustic potash, a procedure which is the foundation of the process for making it into the common commercial articles extensively sold under the names of oswego, cornflour and hominy. If imperfectly cooked, or at all decomposed, maize may give rise to very disturbing symptoms. The grain, too, is liable to a peculiar disease due to a fungus called *Sporisorium maidis*, which gives rise to a disease in man known as "pellagra," and closely resembling scurvy. This affection is not uncommon in Lombardy, where much maize is eaten as food. The starch grains of oats, rice, and maize, somewhat resemble each other, in being all of them faceted. The maize starch grains (Fig. 32) are much larger than the other two,

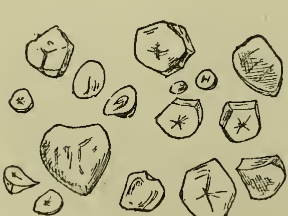


Fig. 32.—Maize.

with a distinct hilum; oat and rice starch grains are smaller than those of maize, and are usually without a hilum, while both the oat and rice grains have a tendency to collect together into clumps.

Peas and Beans.—These belong to the leguminous group of seeds, which also includes lentils. They have a high dietetic value, in consequence of the large amount of proteid which they contain; this is called *legumin*, or vegetable casein, and exists largely in combination with sulphur and phosphorus. Both peas and beans are less digestible than the cereals, and require to be boiled slowly for a long time. Added to rice, foods of this class largely furnish the nitrogenous material in the diets of the natives of Hindustan; but to those unaccustomed to such, it is doubtful whether leguminous seeds can replace the animal proteids. Their large amount of contained proteid adapts them for consumption in association with starchy and fatty articles; a familiar example in our own country being beans and bacon. Unfortunately they are difficult of digestion. The starch grains of peas and beans (Fig. 33) are characteristic, being oval or kidney-shaped; they have no clear hilum, but usually a deep central longitudinal cleft, or at times an irregularly shaped depression. The addition of hot water to pea or bean flour causes the emission of the typical beany smell. Closely allied to the foregoing foods are the potato, the various arrowroots, sago and tapioca.

FIG. 33.—Pea flour.

Potatoes.—These may be considered as occupying a place next in importance to the seeds of the cereals as articles of vegetable food. The potato, used as food, constitutes the tuber or exuberant growth of a portion of the underground stem of the *Solanum tuberosum.* The tuber develops into a thick fleshy mass, retaining its buds under the name of "eyes," each of which eyes or buds is capable of independent growth when in a detached or isolated state. In its chemical composition, the potato shows a large proportion of starch with a very small quantity of proteid. The juice of the potato is acid, due to the presence of a certain amount of free citric acid with citrates of potassium, sodium and calcium. In its dietetic value, the potato is both a carbohydrate and an antiscorbutic. The starch grains of the potato (Fig. 34) are characterized by being large oyster-shaped granules with well-marked concentric rings, and a clear though small hilum at the

narrow end. Potato starch is largely used for adulterating the more expensive farinaceous dietetic preparations; though cheaper, there is nothing to show that potato starch is less nutritive than other starches. Potatoes require to be cooked before being eaten; this may be done by either steaming, boiling, baking, or frying. The heat coagulates the albuminous juices, and the absorbed water swells up and distends the starch grains. When these changes are complete, the potato is said to be mealy or floury; when these changes are only partially completed, and the starch cells imperfectly broken up and separated, the potato remains more or less firm, and is spoken of as being close, waxy, or watery. The potato plant is sometimes affected with a fungus—the *Phytophera infestans*—which causes the disease known as potato murrain. This can be readily detected by the microscope. The disease commences in the leaves of the plant, and thence extends to the stem and on to the tubers. On the surface of the latter, brown spots make their appearance, penetrate the potato, and eventually cause it to rot and decay.

FIG. 34.—Potato starch.

Arrowroots.—The arrowroots are obtained from various sources. Originally the term arrowroot was applied to the starch from the tuber or rhizome of the *Maranta arundinaceæ*, because that root was supposed to have the power of counteracting the effects of poisoned arrows. The term is now applied to a great variety of starches, but, strictly speaking, should be limited to those known in commerce as Canna, Curcuma, Maranta, and Tacca arrowroots. The roots of the plants are dug up when about a year old, washed, and reduced to a pulp. This is repeatedly washed, passed through coarse sieves to separate the fibres, and the starch allowed to settle, which again is washed and dried. When finished ready for exportation, arrowroot is a white, tasteless, odourless substance, firm to the feel, and producing, on pressure, a slight crackling noise. Arrowroot, being a pure starch, has no dietetic value beyond that peculiar to this substance. It is chiefly used as a bland article of food for invalids, or, in an ordinary way, as blancmange, puddings and biscuits.

Canna arrowroot is often called "Tous les mois," and is furnished by the *Canna edulis*, a native of the West Indies. Its starch grains are very like potato, but, on the whole, are larger and flatter with more definite striæ, or markings.

Maranta arrowroot, sometimes spoken of as Bermuda arrowroot (Fig. 35), is derived from the *Maranta arundinaceæ*, a plant which grows in Jamaica and Bermuda. Its granules are long and ovoid; the rings, or striæ, are well-defined; while the hilum is in some circular, and in others a mere transverse line or slit.

Fig. 35.—Arrowroot starch.

Curcuma arrowroot is furnished from the *Curcuma angustifolia*, a species of turmeric plant. Its starch grains vary much in size, being, as a rule, flat and elongated. The striæ are not complete circles, and the hila, if present at all, are at the narrow end of the grain.

Tacca arrowroot is obtained from the *Tacca oceanica*, growing in Tahiti. Its granules are truncated, or wedge-shaped at one end. Their striation is indistinct, with a more or less circular hilum. All these starches of arrowroots readily form clear jellies on cooling after being heated with water. The true arrowroots are chiefly adulterated with potato, sago and tapioca. What is called English arrowroot is merely potato starch.

Tapioca is a starch (Fig. 36) in the form of small granules, truncated at one end with large bases, indistinctly ringed, and

Fig. 36.—Tapioca starch.

Fig. 37.—Sago starch.

with a more or less star-shaped hilum at the apex. It is prepared from the roots of the *Jatropha manihot*, or *Cassava*, growing in the Brazils.

Sago is another starch (Fig. 37) obtained from the interior of the *Sagus farinifera*, or sago palm, growing in Sumatra. The starch grains are very similar to those of tapioca, but larger.

Among the large class of succulent vegetables are such common articles of everyday life as cabbage, carrots, parsnips, turnips, beetroot, lettuce, etc. These can scarcely be regarded

as foods, because the greater part of their carbohydrates exists in the indigestible form of cellulose, while their contained water amounts to about 90 per cent. Their general percentage composition may be put as—proteid 2, fat 0·5, carbohydrate 7, salts 1, water 89·5. All these vegetable foods are valuable for their antiscorbutic properties and for the salts which they contain; their absence from a diet leads to the production of scurvy.

The fruits are chiefly esteemed for their taste; though being, as they are, rich in water, vegetable acids and salts, they are distinctly of service as preventatives of scurvy. Some fruits, such as grapes, contain sugar; while others, like dates and bananas, contain not only sugar, but starch. When eaten, fruit should not only be ripe, but quite free from decomposition. Some few, like dates and figs, can be dried, but the softer and more perishable varieties cannot be too fresh when eaten.

Lemons.—Owing to its great antiscorbutic powers, the lemon, or fruit of the *Citrus limonum*, is deserving of special notice. Its use as lemon-juice has practically eradicated scurvy from both the navy and mercantile marine. Lime- or lemon-juice, as met with in commerce, is chiefly prepared in Sicily or the West Indies. To preserve it, it is mixed with brandy or whisky in the proportion of about 1 oz. of spirit to 10 ozs. of juice, and olive oil is poured on the top to exclude air. Sugar, in the proportion of half its weight, is also added, to improve the taste. In the absence of fresh vegetables 1 oz. of lemon- or lime-juice is the daily issue for the prevention of scurvy. Both lemon- and lime-juice contain large quantities of citric acid with some malic acid, proteid and sugar. The citric acid, which is the most important constituent, averages from 7 to 8 per cent. Apart from their value as antiscorbutics, both lime- and lemon-juice furnish agreeable and refreshing beverages; they allay thirst and sickness, and too are of special value as antidotes in poisoning by the alkalies. A good and pure lemon-juice should be clear, with an acid but not bitter taste, and possessed of a distinct aroma of the fruit. Many substitutes for lemon-juice are sold, the chief being a solution of citric acid in water flavoured with essence or oil of lemon. The chief adulterations are watering, and the additions of sulphuric and tartaric acids. The addition of water can be detected by the lowering of the specific gravity below 1030, and the diminution of the acidity below 30 grs. of citric acid per ounce. Sulphuric acid is probably the most important adulteration; it may be detected by filtering, and, after acidulation by hydrochloric acid, treating with chloride of barium, when the insoluble barium sulphate is thrown down, if sulphuric acid be present.

Food Accessories.—This term has been proposed for the great group of condiments and beverages, because they include food stuffs which, though not absolutely necessary for existence, are still of much importance as aids to digestion and to the relishing of the more ordinary articles of diet. The Germans call them "means of enjoyment," as distinguished from the true foods or "means of nourishment." They include substances varying from the simplest aromatic principles, such as one smells when meat is cooking, or condiments and spices, to the more complex alcoholic and non-alcoholic drinks which so largely enter into the daily dietaries of both civilized and uncivilized peoples. The general action of the food accessories seems to be to stimulate digestion, either directly by affecting the digestive organs, or indirectly through the central nervous system. The condiments are mainly added to food as flavouring agents; they include such articles as mustard, pepper, onions, cloves, nutmeg, cinnamon, salt and vinegar. Excepting the two last, all these owe their value as food accessories to aromatic oils which they contain. These essential oils are all stimulants directly of the muscular movements of the digestive organs and of the secretion of their juices; but if taken in excess, easily induce gastric catarrh and exhaustion of the mucous lining of the stomach. The influence of common salt has already been discussed.

Vinegar is dilute acetic acid, more or less contaminated with gum, sugar, vegetable matter, etc. The varieties of vinegar met with in the market are wine vinegar, malt vinegar, and wood vinegar. The first two are produced by fermentation of alcohol, the process being one of oxidation from alcohol into aldehyde and then into acetic acid; the last by the destructive distillation of wood and subsequent separation of the acetic acid. The percentage of acetic acid ought not to be below 3 per cent., while in the best vinegars it may be as high as 6 per cent. Its specific gravity, if a wine vinegar, varies from 1015 to 1022; if a malt vinegar, from 1016 to 1019: anything below these figures is suggestive of dilution with water. The chief adulteration of vinegar is the addition of sulphuric acid in excess of that permitted by law, namely 1 in 1000. If an excess be suspected, it must be determined by barium chloride. Occasionally, artificial vinegars are sold, being really nothing more than very dilute acetic acid coloured with caramel; they lack, however, the odour and bouquet of the volatile ethers which are so characteristic of the alcoholic fermentation products. The use of vinegar is not only that of an aid to food relishment, but, like other vegetable acids, helps to maintain the alkalinity of the blood, by conversion of the acetic acid into carbonates within the body. In doses of

from half to an ounce daily, vinegar is an antiscorbutic, though inferior to lime- and lemon-juice. It is also an aid to digestion, particularly of some shell-fish, such as oysters and mussels. If taken in excess, especially when adulterated with sulphuric acid, vinegar tends to impair digestion.

The beverages included among food accessories may be divided into those which contain no alcohol and those which do. The non-alcoholic beverages owe their action as food accessories chiefly to the alkaloids they contain; the more common of these beverages are tea, coffee and cocoa; the two former have as their active principle the alkaloid theine or caffeine, while cocoa contains theobromine. Theine or caffeine is essentially a brain stimulant, exciting it to continued activity. If taken in excess, it produces not only an exhausted and disordered nervous system, but gives rise to acid dyspepsia and considerable delay in the digestive process. Theobromine, though closely allied in its chemical nature to caffeine, has a slightly different physiological action, exerting its effects rather upon the muscular system, which it stimulates into activity, than upon the nervous system.

Tea consists of the dried leaves of a shrub called the *Camellia thea* which grows in China, India, Ceylon and Japan. As met with in everyday life, tea leaves are curled, but they uncurl on being placed in hot water, and when so treated, are found to be ovate in shape, pointed, and with a margin toothed like a saw almost to the stalk. The arrangement of the veins in the tea leaf is characteristic; the large veins do not reach to the border of the leaf, but turn in towards the midrib. The size of the leaves varies, and usually with them is some stalk. Practically all tea in the market is grown from the same species of shrub, the various names given as indicating different kinds are only trade names, and do not indicate really different varieties of tea leaf so much as different qualities dependent upon mixing or blending, and on the age of the leaves, or on the soil on which the plant has been grown. In all cases, the leaf most highly valued is the small top leaf of the twig and the bud. Possibly these small leaves are neither finer in quality nor richer and better in flavour than the leaves next in succession, but being more tender and softer in structure give better and more flavoured infusions. The various teas known under the trade names of Orange Pekoe, Pekoe, Suchong, Congou are all the same in respect of origin; they are picked at the same time from the same shrub. The bud and top leaf constitute Orange Pekoe, the two or three larger leaves growing on the same twig a little lower down are Suchong, and below that the leaves become Congou.

The most simple division of teas is into the green and the

black; both are from the same plant, the only difference is their colour. Green tea is now little used, in consequence of the disrepute into which it fell as the result of the artificial colouring it received; but real green tea owes its colouration to being dried over wood fires when fresh. Black teas owe their colour to the leaves having been allowed to lie in heaps for 12 hours, during which they undergo a process of fermentation and are afterwards dried slowly over charcoal fires. "Brick tea" is made from the refuse, broken leaves and twigs, moulded into shapes. "Lie tea" consists of the dust of tea and other leaves made up by means of gum or starch into little masses, which are coloured or painted so as to resemble black or green tea; it is called "lie" tea because it is a false article and not tea at all. In selecting a fine tea, one should not be guided by any trade name, but determine, by pouring a little boiling water over the leaves and examining them, whether the leaf was a whole leaf and not a large leaf cut into small pieces. The larger the leaf, the weaker will be the infusion and the less the value. What are called "digestive" teas are varieties in which the tannin of the tea has been so altered by electrical treatment that it does not precipitate gelatin, and interferes but little with the digestion of starch.

The average percentage composition of tea may be expressed as follows:—

Water	8·0	
Theine	2·6	
Tannin	14·0	
Oil	0·4	
Extractives	15·0	
Insoluble organic matter	54·0	
Ash	6·0	Potash, iron, silica, alumina, magnesia.

Formerly, the chief adulteration of tea was by mixing with it other leaves, such as those of the sloe and willow, which have a superficial resemblance to tea leaves. At the present time the chief adulteration of tea is the admixture of old and exhausted tea leaves, while in the inferior kinds there is often clay, lime, or ferruginous sand. The total soluble matters obtainable from tea are a ready and convenient index of its quality: they are estimated by infusing a weighed quantity with an excess of distilled water, and evaporating this down to dryness; the amount of extract so obtained should be at least 30 per cent. If the sample contain many exhausted leaves, the amount of extract obtained will be, of course, less than this. The ash obtained by burning a given quantity of the tea sample should, in a good specimen, be at least 5 to 6 per cent., and not more than 8 per

cent.; and of this at least 3 per cent. or half should be soluble. The precise estimation of the theine and tannin are matters of some difficulty, but are not certain data upon which to judge the purity of any particular sample.

The most essential points in making good tea of the finest quality and with the least waste are to have actually boiling water, and tea leaves so crushed and subdivided that the largest possible surface is rapidly exposed to the boiling water in infusing it. This explains why the best tea made in the world is that made by the Japanese from their carefully prepared "tea powder," which is made by crushing to a fine powder certain well-selected leaves. The tea bricks of China probably owe their superiority to being well-crushed leaves of good quality. The use of tea-powder, obtainable in Europe, is handicapped by its liability to adulteration, its uncertain mixture and difficulties in its preparation. Possibly these disadvantages may be overcome by a more extended employment of tea tabloids, made by the compression of carefully selected and finely ground teas from Japan, India and Ceylon.

The excessive drinking of tea is bad, especially when fasting. Tea is not a food, and should not be taken as such; but if used in moderation, it undoubtedly serves a useful purpose among our daily wants. It is essentially a stimulant of the brain and nervous system, producing no subsequent depression; but if taken in excess induces indigestion, loss of appetite and constipation: in some persons, these bad effects are produced even when only small quantities are consumed.

Coffee is the seed, or berry, of the *Caffea Arabica*, a plant growing in most parts of the tropics, but chiefly in Arabia, Abyssinia, Ceylon and the West Indies. After the seeds have been roasted to a chocolate brown, they are ground to a powder in a mill, and then used in the form of a decoction or infusion. The percentage composition of unroasted coffee may be expressed as follows:—

Water	11·23
Nitrogenous matter	12·07
Caffeine	1·21
Fat	12·27
Sugar or dextrin	8·55
Tannin	32·79
Cellulose	18·17
Salts	3·71

The chief properties of coffee depend upon an aromatic oil and an alkaloidal body called caffeine. Caffeine itself is a nitrogenous crystalline alkaloid identical with theine; in the roasting of coffee this body is not destroyed, but dissociated, as it were,

from its previously existing combination with tannin. During the same process the sugar and dextrin are changed into caramel, and the gas and water of the berry are driven off.

The adulterations of coffee are chiefly chicory, but at times dates, beans, maize and acorns have been added. Chicory is a legal addition to coffee, provided such admixture be stated, no limit being fixed as to their relative proportions; as a rule it amounts to about 30 per cent. The addition of chicory to coffee is considered by most people to add to its flavour. It is probable that much of the present decadence of coffee drinking is due to the excessive addition of chicory, whereby the resulting infusion is wanting in the desired alkaloid caffeine. To make good coffee the berry must be freshly roasted. Good drinkable coffee requires as much as an ounce of recently roasted and ground coffee to each large cup, the result of which means that the cost of a cup of good coffee, including milk and sugar, is about twopence. The prevalent custom of making coffee in this country is to use barely an ounce to two pints of water, the resulting infusion being more or less mawkish, tasteless and wanting in stimulating properties. Chicory itself is the dried and powdered root of a plant called the *Cichorium Intybus*. In composition it differs much from coffee, containing no caffeine, less fat, but more sugar. It may be readily distinguished from coffee by the fact that when thrown into water it rapidly sinks and colours the liquid brown, while coffee floats and does not yield any colour. If adulterations are present in the form of the starch grains from various cereals, both a microscopical examination and the blue reaction with a dilute solution of iodine will betray them.

Coffee, like tea, appears to act decidedly upon the nervous system, which it stimulates, causing wakefulness and increased brain action. In some people it has an aperient action by stimulating the muscular coats of the intestines.

Cocoa is the roasted seed of the *Theobroma cacao*, growing chiefly in the West Indies. Cocoa nibs are the seeds or beans roughly broken; flake cocoa is the same completely ground and crushed; soluble cocoa is the same freed from cellulose; while prepared cocoa is the same after half or more of its contained oil or fat has been removed, and in most cases starch and sugar added. The percentage composition of cocoa beans may be said to be as follows:—

Water	6·0
Theobromine	1·5
Fat	50·0
Starch	10·0
Salts	3·6
Gum	8·0
Cellulose	20·9

Theobromine closely resembles caffeine, not only in its nature, but in its action. The adulteration of cocoa is chiefly in the direction of the addition of sugar and starch, which the microscope will detect; while, by some, the removal of the fat, so as to reduce it below 20 per cent., is regarded as an adulteration. Apart from cocoa by nature containing nitrogenous and fatty matter, in its commercial forms it contains so much starch and sugar that it is rightly regarded to some extent not only as a proteid and fatty food, but also a carbohydrate one. Cocoa differs much from both tea and coffee in having but little stimulant action, but it does possess some nutritive value, and, as such, may in a limited sense be regarded as a food.

Chocolate is a preparation of cocoa, from which the greater part of the fat has been removed, and which, after being mixed with sugar and various flavouring substances, is made into a paste with water, and then pressed in moulds.

Aerated Waters.—In addition to the large number of natural waters rich in carbonic acid, there are many artificial aerated waters which have come into general use of late years. The peculiar feature of them all is that they are prepared by forcing carbonic acid into ordinary water, and adding to it either some saline or a flavouring agent. Much of what is known and largely sold as "soda water" really contains no soda at all, but is merely an ordinary water highly aerated and charged with carbonic acid. If the gas, naturally present in the water, is not previously thoroughly expelled, the carbonic acid is imperfectly dissolved, and when the bottle is opened, tends to froth and escape violently. The chief sources of danger in these beverages lie in the possible employment of originally impure water; the making of the carbonic acid from impure materials; the presence of either lead, copper or tin, as the result of imperfect washing of the gas, or derived from the plant used in the manufacture. These dangers can only be obviated by the exercise of care in the selection of the water and materials used. Fortunately carbonic acid, under pressure, is a poison to the majority of micro-organisms present in water. This is a fact which may in great measure explain the remarkable immunity from filth diseases, such as enteric fever and cholera, which attends the habitual use of highly aerated waters in place of the ordinary supplies. It would, however, be desirable if legislation could make it illegal to use any water but that possessing all the qualities of an unobjectionable drinking water for the making of aerated beverages. The presence of any deleterious metals is uncommon in these drinks, except those made in inferior and faulty machines. The aerated waters stored in bottles with patent stoppers of porcelain, glass and vulcanite

are, of course, the most generally free from any of the hurtful metals. It is questionable whether any real danger exists to health under this heading.

Alcoholic Beverages.—Among the alcoholic beverages, the chief are beer, wine and spirits; these all owe their action as food accessories partly to the alcohol and partly to certain aromatic principles and substances which they contain. The alcoholic beverages are sometimes called fermented liquors, because the alcohol contained in them is the result of a process called fermentation set up in either the natural sugars which we extract from fruits, stalks, or roots of certain plants, such as the grape, the sugar-cane and the beetroot, or in the secondary sugars which we prepare by art from potatoes, cereal grains, malt and the starches generally.

If we take a natural sugar, such as grape sugar present in the fruit of the vine, dissolve it in water and add a little yeast to it, the solution quickly begins to ferment. During this fermentation the sugar is split up into alcohol and carbonic acid. The former remains in the liquid, while the carbonic acid escapes as a gas in bubbles into the air. The yeast which brings about this remarkable change is in reality a microscopical plant, made up of oval cells about $\frac{1}{2000}$ of an inch in diameter, filled with granular matter. The scientific name for yeast is *Torula cerevisiæ*. It is by virtue of this fermentation of grape juice, as we shall learn later, that wine and brandy are made. If instead of grape sugar, we take common cane sugar, dissolve it in water, and mix with yeast, fermentation is set up in a similar way; excepting that the cane sugar is first changed into fruit or grape sugar by the action of the yeast, and then the grape sugar is split up into alcohol and carbonic acid. These changes go on whether the sugar be exposed to the air or not. If now, instead of taking either grape sugar or cane sugar, we take some ordinary starch, boil it in a dilute solution of almost any acid, particularly 1 per cent. of sulphuric acid, the starch is converted into a sweet gum-like body called dextrin, and subsequently into a kind of sugar called maltose, which closely resembles in sweetness, chemical composition and general properties that of the grape. If yeast be now added to this altered starch, the same fermentation and production of alcohol takes place. It is from potato starch treated in this manner that large quantities of spirit, known as potato brandy, are manufactured in various countries.

In a previous chapter it has been explained that the cereal grains consist essentially of two principal substances—namely, starch and a nitrogenous body of the nature of a globulin or albumose. These evidently are intended by nature to afford the first food of

the young plant as it grows from the grain; but in their natural state these are insufficiently soluble to supply the wants of the growing germ. Under the influence of moisture, as when a grain of wheat sprouts, a ferment in the form of a soluble white substance called *diastase* is formed in the grain, which so converts the nitrogenous elements of the seed as to make it usable by the young plant, and for the same purpose also changes the insoluble starch into soluble starch, dextrin, maltose and glucose or grape sugar. This is why sprouted corn always has a sweet taste. The maltster, brewer and distiller avail themselves of this natural change in the constituents of sprouting grain, and on a large scale call into action the chemical influence of this unorganized ferment known as diastase.

In the manufacture of all fermented drinks, therefore, two distinct chemical processes are involved; there is first the change of the starch into sugar, and secondly the change of the sugar into alcohol and carbonic acid. This latter we know is brought about by fermentation through the medium of yeast, while the former may be secured by the artificial conversion, by means of sulphuric or other acid, of potato or other starch into sugar; or the grain may be manufactured into malt and the remarkable influence of diastase called into play.

The essential element in all fermented drinks, no matter how made, is alcohol, which is a neutral compound of oxygen, carbon, and hydrogen, having the chemical formula of C_2H_6O. When quite pure and free from water, alcohol is termed *absolute alcohol*, having a specific gravity at 60° F. of 0·79381; when mixed with 16 per cent. of water, it is called *rectified spirit*, and when mixed with 56·8 per cent., volume in volume of water, it constitutes *proof spirit*. Proof spirit is a term constantly in use for excise purposes, signifying a dilute spirit of definite strength. If expressed as volume in volume, proof spirit contains 56·8 per cent. of absolute alcohol; if as weight in weight, 49·25 per cent.; if as weight in volume 45·4 per cent.; the remainder in each case being distilled water. The ratio of alcohol to proof spirit in each of these cases being for volume in volume as 1 is to 1·76; for weight in weight as 1 is to 2·03, and for weight in volume as 1 is to 2·21. We can, therefore, if in any case the percentage of contained alcohol be known, calculate the amount of proof spirit present by multiplying the given percentage of alcohol by any of the foregoing ratios.

Spirits which are weaker than proof are described as being *under proof;* when stronger than proof as being *over proof.* Thus, say a sample of whisky is found to contain 70 per cent. volume in volume, of alcohol; then $70 \times 1·76 = 123·2$, and the

excess of this product over 100 or 23·2 gives the number of degrees over proof which the sample has. If, on the other hand, it contain but 24 per cent. of alcohol, volume in volume, then $24 \times 1{\cdot}76 = 42{\cdot}24$, and by just so much as this figure is greater or less than 100 is the sample degrees over or under proof, that being, in this case, just 57·76° under proof. Conversely, if the degree of strength of any spirit over or under proof be known, the percentage of alcohol present can be calculated either as volume in volume, weight in weight, or weight in volume. Thus, say a sample of brandy be x degrees over proof; then $\frac{x + 100}{1{\cdot}76}$ gives the percentage, volume in volume, of alcohol which it contains. If it be x degrees under proof, then $\frac{x - 100}{1{\cdot}76}$ gives the percentage, volume in volume, again of alcohol.

Nutritive Use of Alcohol.—The use of alcohol by man is of very ancient origin, and owing to the ease with which alcohol is produced by fermentation from sugars and starches, its early discovery and almost universal use throughout the world are not at all remarkable. In attempting to understand the physiological action of alcohol, one must bear in mind that there is a distinction between the effects of alcohol taken in dietetic doses and when taken in excess, and too, that the physiological action of pure alcohol is not quite the same as that of many alcoholic beverages, because many of these contain other bodies besides alcohol, and which have a distinct action of their own. Moreover, it must not be forgotten that what is a dietetic dose for one person is an excess for another. As based upon the experiments of Parkes, Anstie and others, the amount of alcohol which can be taken daily by the average individual without doing harm is between one and two fluid ounces. This is contained in about two ounces of ordinary spirit, such as brandy or whisky, and in half a pint of the light wines, such as clarets and Burgundies, or in about one and a half pints of the ordinary beers and ales.

It is still a matter of dispute as to how alcohol is eliminated from the body, and whether any of it is destroyed in the tissues. The probable truth is that alcohol is oxidized in the body, the products being excreted in the urine. In small doses, alcohol stimulates the nervous system, reddens the lining membrane of the stomach, increasing the secretion of the gastric juice, and thus may in very small doses promote the appetite. When carried into the circulation, it increases the heart's action and at the same time causes the smaller blood-vessels or capillaries to dilate. It is an unsettled question as to how far alcohol

lowers the body temperature in health, but it is beyond question that it tends to lower the natural resisting power of the body against cold, and is in consequence unsuited for those exposed to great degrees of cold as in the Arctic regions. If taken too often, even in small doses, or taken in any large quantity at one time, alcohol instead of stimulating the nervous system actually depresses and paralyzes it as evidenced by intoxication. In these circumstances the perception power of the brain is depressed or paralyzed, correct judgment is impossible, while speech is disordered and the emotions out of all control. If repeatedly taken to excess, alcohol delays digestion, causes catarrh of the stomach and bowels, accompanied by such degenerated conditions of both the liver and kidneys as to result in death. It is beyond question that, when taken in sufficient quantities to produce these effects upon the brain and nervous system, alcohol causes an immensity of harm; the physical, moral and social evils of intemperance are only too familiar to us all. But how far alcohol is beneficial or not when taken in small or dietetic doses is still a matter of controversy between the teetotallers and those who advocate moderation. Of one thing there can be no doubt, as all are agreed upon it, namely, that a person can do quite as hard if not harder work without alcohol than with it; the experience of wars and expeditions in all climates, where abstinence was either enforced by order or by circumstances, shows that soldiers endure more fatigue, are healthier and fight better without alcoholic stimulants than with them. On the other hand, it must be borne in mind that in ordinary life to many the cares and worries of business and existence are such that to them, after the labours of the day, a moderate amount of alcohol in some form or other is not only an advantage but almost a necessity. To the old and feeble, the use of alcohol is not less valuable. In all cases, however, it should be remembered that alcohol should never be taken during working hours with the idea that the body and brain are likely to do more work after it than before; the only time when it can be advantageously used is after the day's work is done; so taken, its influence is often to check tissue change and waste, to soothe and stimulate an exhausted brain with a removal of the sense of fatigue and to promote digestion. Alcohol should never be taken fasting, its best effects are secured when taken with food, and at no meal more so than at the late dinner or supper.

Beer.—The usual definition of beer is, that it is a fermented infusion of malt flavoured with hops. This, however, is not quite correct at the present day, as sugar largely takes

the place of malt, and other vegetable bitters that of hops; so that probably a more accurate definition would be, to call it a fermented saccharine infusion to which has been added any wholesome bitter. Formerly the substitution of quassia, gentian, calumba, or any other bitter in place of hops was illegal, but now it is not the case, with the result that all kinds of bitters may be used provided they are wholesome. As a matter of fact, however, in the best beers even now, the only bitter used is hops.

Modern beers may be divided into two great groups, namely, the non-malt beers and the malt beers. What are called non-malt beers are those made by a yeast fermentation of an infusion of sugar, mainly derived from starch chemically or artificially converted, as by the action of sulphuric acid. Malt beers are the result of a similar yeast fermentation of an infusion of sugar, only in this case the sugar is derived from the natural conversion of grain starch by means of germination or malting. In both instances, the resulting liquor is an alcoholic one in which a portion of the alcohol becomes transformed into aldehyd and subsequently by a further oxidation changed into acetic acid.

The actual preparation of malt and the subsequent brewing of beer is easy to understand. The maltster first soaks his barley in a cistern for some fifty hours; he then transfers it to the "couch," and twenty hours later spreads it out on floors in a malting. Here he leaves it for ten or fourteen days, during which time germination takes place and the grain sprouts. After this sprouting has taken place sufficiently, all germination action is arrested by drying the grain over a kiln. It is now malt, and if tasted is distinctly sweet, owing to the conversion of the grain starch into sugar by the action of the diastase ferment, as explained a few pages previously. After the dried malt has been sifted or screened so as to break off all the sproutings, it passes into the hands of the brewer, who, after crushing it, places it in his mash tub with water warmed to about 160° F. This water completes the transformation of the starch into grape sugar and dissolves it, causing the resulting liquor, or *wort* as it is called, to have a decidedly sweet taste. In the case of a brewer using chemically converted starch or a mixture of it with malt, a similar treatment with warm water would be followed with the production of a sweet liquor or wort. When the conversion of the starch into sugar is sufficiently complete, all chance of further conversion is stopped by boiling the wort, which also acts in coagulating the albumin which the water has dissolved out of the grain; advantage is also taken of the

boiling to add hops which aid further in clearing the wort by coagulating the remaining albuminous matter, besides imparting to it their characteristic bitterness. Both the length of the boiling and the quantity of hops added vary according to the richness of the wort in sugar, and with the quality of beer it is intended to make.

The next step in brewing is to run off the boiled liquid into shallow vessels, in which they are cooled to the best temperature for fermentation. If "top" yeast is going to be used, this temperature is 60° F., but if what is called "bottom" or sedimentary yeast, as used in Bavaria, a much lower temperature is preferable. When at the required heat, the liquid is run into the fermenting tun and a sufficient quantity of yeast added. It is usual to use a yeast obtained from a kind of beer different from that which it is proposed to make; the whole is allowed to ferment slowly for six or eight days. During this time, the sugar splits up into alcohol which remains in the beer, and into carbonic acid gas which, for the most part, escapes into the air. The most essential points in brewing are the facts that the quantity of yeast to be added and the temperature at which fermentation is allowed to take place, vary with different kinds of beer; also that yeast works better when transferred from one kind of beer to another; and that the fermentation must be so regulated that the whole of the sugar contained in the wort is not transformed into alcohol, as if it is all so transformed the beer has no keeping power; that is, it would turn sour in the casks. This turning sour is due mainly to the passage of the alcohol into aldehyd and the subsequent oxidation of this into acetic acid.

There are many varieties of ales and beers, the chief being: *Pale* and *Mild Ales*, made from the finest dried malt and the best hops; the mild ale is usually sweeter, stronger and less bitter than the pale. *Porter* is nothing more than a weak mild ale, coloured and flavoured with roasted malt. *Stout* is a richer and stronger kind of porter. The *German Beers* are fermented by means of sedimentary yeast as distinguished from the surface yeast used in England. Their fermentation is carried on at a lower temperature than in the case of British beers. They contain also less alcohol than the English, but are richer in carbonic acid gas, and keep better. *Lager* and *Bock* beer is made from a stronger wort, and is proportionately richer in alcohol and malt extract. The *Belgian beers* are made with unmalted wheat and barley; they take long periods to ferment, doing so spontaneously, no yeast being added; as a rule, they are hard from the presence of much acid. *Bottled beers* are all bottled while

fermentation is going on, and owe their sparkling and frothing to the excess of carbonic acid in them.

The chief constituents of ales, stouts and porters are—alcohol, dextrin, sugar, hop resin or oil, glutin, acetic and lactic acids, carbonic acid gas, mineral ash and water. The alcohol in beer varies from 1 to 10 per cent. in volume. The free acidity which arises chiefly from acetic, lactic and malic acids, if expressed as acetic acid, ranges from 15 to 40 grs. per pint. The malt extract, which consists mainly of sugar, dextrin and cellulose, varies from 4 to 15 per cent.

Regarded as a food, the nutritive value of beer is small, though, of course, higher than other alcoholic drinks, owing to the large amount of maltose, dextrin and other saccharine substances which it contains in the form of malt extract. In the main, its dietetic effects are those of alcohol, modified by the associated action of other ingredients. Beer appears to have some action peculiarly its own ; this is generally attributed to *lupulin*, which is the active principle in hops. On some people, beer acts as a depressant, and, if taken in excess, it undoubtedly is a soporific or stupor producer. Beer also seems to exercise slight but continuous interference with tissue change, with a tendency to fatten and produce gout and rheumatism. When drunk to any excess, beer appears to have a retarding effect upon digestion.

In its general characters a good beer should be transparent with a red-brown colour, and possessed of a semi-vinous flavour. Formerly, many hurtful ingredients were added to beer as adulterants, but in the present day, practically the only adulterations are water with occasionally salt or alum. Salt is usually present in small amounts in the best beers, being derived from the water and other ingredients in making; but if present in excess of 10 grs. per gallon amounts to an adulteration. Alum is sometimes added to beer combined with salt, and sulphate of iron or even sugar in order to raise the density and give a "head" after dilution with water. Such beer soon undergoes secondary fermentation and becomes sour, heady and unwholesome. The quality of ale is most conveniently estimated by a determination of the amounts of its acidity and its contained alcohol. For determining the acidity of beer, we need an alkaline solution of known strength, of which 1 c.c. is equal to 6 mgms. of acetic acid, and 9 of lactic acid. The amount of this solution required to exactly neutralize a given quantity of beer is determined and expressed as acetic acid in grains per pint. This, representing the *total* acidity of the beer, rarely exceeds 30 grs. per pint, more commonly is about 15 grs. per pint. The total acidity of a beer

can be divided into *fixed* and *volatile* by evaporation down to one third, and then making up to original bulk with distilled water. The volatile acetic and carbonic acids being thus driven off, the acidity as now determined represents the fixed acidity, and is usually expressed as lactic acid.

Example.—Say 10 c.c. of beer are exactly neutralized by 6 c.c. of standard alkaline solution: $6 \times 6 = 36$ mgms. of acetic acid in 10 c.c. of beer; this $36 \times 7 = 252$ grs. of acetic acid in a gallon of beer, and $252 \div 8 = 31{\cdot}5$ grs. of acetic acid per pint, being total acidity.

After boiling, say 200 c.c. of the beer down to one third, allowing to cool and then making up to original bulk with distilled water, say 10 c.c. require 5 c.c. of the alkaline solution; this acidity, which is the fixed acidity, is expressed as lactic acid, we calculate thus, $5 \times 9 \times 7 \div 8 = 39{\cdot}3$ grs. of lactic acid per pint, being fixed acidity.

The difference between the amounts of alkaline solution used, $6 - 5 = 1$ multiplied by $6 \times 7 \div 8 = 5{\cdot}25$ grs. per pint of acetic acid, being volatile acidity.

To determine the amount of alcohol in beer, it is necessary to first take its specific gravity at 60° F. Next evaporate the beer down to one third, allow to cool, measure and remake up to original bulk with distilled water. The act of evaporation will have driven off all the alcohol. Take the specific gravity of this de-alcoholized beer at 60° F. Deduct the gravity before evaporation from that after it, and take the difference from unity which is the specific gravity of pure water. Refer to the table of specific gravities on p. 173, and read off opposite the number obtained the percentage of alcohol present.

Example.—Say 200 c.c. of beer are taken, and its sp.gr. at 60° F. is found to be 1·012; after boiling down to one-third, it is allowed to cool, measured, and made up with distilled water to 200 c.c. Its sp.gr. is now taken again at 60° F., and found, say to be 1·020. The difference between the first sp.gr. and the second is 0·008, and this deducted from 1·000, gives 0·9920; on referring to the table, we find that the nearest specific gravity given to this figure is 0·9919, corresponding to 5 volumes of alcohol per cent, and that consequently 0·9920 lies between 0·9919, and the one next above, namely 0·9933, and that the percentage of alcohol corresponding to 0·9920 is something between 4 and 5 volumes. To find how much it is exactly, we calculate the proportional part. The difference between the gravities for 4 and 5 volumes per cent. of alcohol is 0·0014, and as the calculated gravity of 0·9920 is 0·0013 different from 0·9933, the one above it, and 0·0001 different from the one below it, the percentage of alcohol corresponding to it may be said to be 4, corresponding to 0·9933, *plus* $\frac{13}{14}$ of 1, or 0·928, which gives the exact volume percentage of alcohol, corresponding to a sp.gr. of 0·9920 as being 4·928.

Some idea as to the solids or amount of extract per cent. in a beer can be obtained if, after taking the specific gravity after de-alcoholization, the excess of gravity over 1·000 be divided by 0·004; this gives an approximate conclusion as to the body of the beer; the more extract, the greater is the body of the ale.

In the example given above, the extract would be calculated as being 0·020 divided by 0·004 or 5 per cent.

Specific Gravity at 60° F.	Volumes per cent. of Alcohol.	Specific Gravity at 60° F.	Volumes per cent. of Alcohol.	Specific Gravity at 60° F.	Volumes per cent. of Alcohol.
1·0000	0	0·9596	34	0·8941	68
0·9976	1	0·9583	35	0·8917	69
0·9961	2	0·9570	36	0·8892	70
0·9947	3	0·9556	37	0·8867	71
0·9933	4	0·9541	38	0·8842	72
0·9919	5	0·9526	39	0·8817	73
0·9906	6	0·9510	40	0·8791	74
0·9893	7	0·9494	41	0·8765	75
0·9881	8	0·9478	42	0·8739	76
0·9869	9	0·9461	43	0·8712	77
0·9857	10	0·9444	44	0·8685	78
0·9845	11	0·9427	45	0·8658	79
0·9834	12	0·9409	46	0·8631	80
0·9823	13	0·9391	47	0·8603	81
0·9812	14	0·9373	48	0·8575	82
0·9802	15	0·9354	49	0·8547	83
0·9791	16	0·9335	50	0·8518	84
0·9781	17	0·9315	51	0·8488	85
0·9771	18	0·9295	52	0·8458	86
0·9761	19	0·9275	53	0·8428	87
0·9751	20	0·9254	54	0·8397	88
0·9741	21	0·9234	55	0·8365	89
0·9731	22	0·9213	56	0·8332	90
0·9720	23	0·9192	57	0·8299	91
0·9710	24	0·9170	58	0·8265	92
0·9700	25	0·9148	59	0·8230	93
0·9689	26	0·9126	60	0·8194	94
0·9679	27	0·9104	61	0·8157	95
0·9668	28	0·9082	62	0·8118	96
0·9657	29	0·9059	63	0·8077	97
0·9646	30	0·9036	64	0·8034	98
0·9634	31	0·9013	65	0·7988	99
0·9622	32	0·8989	66	0·7939	100
0·9609	33	0·8965	67		

Wine.—The term wine is held to mean "the fermented juice of the grape with such additions only as are essential to the stability or keeping quality of the wine." This definition admits as wines, those beverages which, made from grape juice, require to preserve them the addition of spirit, as in the case with some wines from Spain and Portugal; but it excludes the so-called British wines, which are not made from the juice of the grape at all, and those wines from other countries, which are fortified with spirit when they require no such addition.

When the sugary juice of a fruit, such as the grape, is left to itself at a moderate temperature, fermentation takes place from the influence and action of germs present in the air; this process differing very much from that in the making of beer, when the starchy or sugary infusion or wort is boiled, and then yeast added to make it ferment. During the fermentation of the fruit juice, a part or whole of the sugar is converted into alcohol. Various ethers, which give the characteristic flavour or bouquet to wine, are formed, as well as acetic, malic, succinic and other acids. The essential acid of wine is tartaric acid; much of this crystallizes in the casks as cream of tartar or tartrate of potash. The newer wines contain aldehyd, which is very intoxicating, later on this gets oxidized into acetic acid, and if exposed to the air long enough, all the alcohol in a wine will be converted into this acid so as to practically become ordinary wine vinegar. Much of the colour, taste and character of wines depends upon how far they are made from the grape juice only, or how much this is mixed with the seeds and skins of the fruit. The seeds are rich in tannin and a bitter principle, while the skins yield a colouring matter, some flavouring principle and tannin.

With regard to the amount of alcohol which a wine contains there is no constancy. All wines can be divided according to their alcoholic strength into two classes; the natural wines, containing from 6 to 13 per cent. by weight of alcohol, and the fortified wines, containing from 12 to 22 per cent. by weight of alcohol. The limit of alcoholic distinction between these two great classes of wine will be more readily understood if it be borne in mind that during the fermentation of any sugary liquid or mass, that process at once ceases when the alcohol formed reaches 14 per cent., so that any excess of alcohol over that amount must, of necessity, have been added artificially. The ports and sherries are all largely fortified with added alcohol; while many of the inferior clarets and champagnes are subject to very similar additions. The strongly alcoholic and fortified wines are slow to undergo change, hence keep well; but the lighter and natural wines deteriorate rapidly when exposed to air.

Like the alcohol, the sugar in wine varies much, being for the most part in the form of fruit sugar. Sherries generally contain about 8 grs. to the ounce. In Madeira it varies from 6 to 66 grs. per ounce; in port, from 12 to 28 grs. In champagnes the average is about 24 grs., but many of the dry champagnes contain none. Wine is acid from the presence of free acid and acid salts, such as tartrate of potash. Wines which have been "plastered" or treated with gypsum or plaster of Paris to clear them, as is the case with many sherries, are deteriorated, owing to the loss of their tartrates.

The chief acids are tartaric, acetic, malic, tannic, succinic, carbonic and fatty acids. The usual acidity of wines, in terms of tartaric acid, is about 2 grs. per ounce in sherry, 3 grs. in champagne, 4 grs. in port and the better kinds of claret, and 6 grs. or more in the inferior clarets. The tannic acid is derived mainly from the seeds and skins of the grape; it is largely present in new port, less so in Madeira and the Rhine wines. The amounts of alcohol and degrees of acidity can be determined in wines in the same manner as explained for beer. It is to the mutual reactions of the acids and alcohols in wine that the formation and presence in them of ethers is due, and it is really to these latter that wines owe their special value as stimulants. The colouring matter of wines is derived mainly from the grape skins; by nature it is greenish or blue, but becomes violet or red by the action of the free acids in the wine. As wine ages, changes occur, resulting in a precipitated combination of the organic bodies with tannic acid, whereby the wine becomes pale and less astringent. Occasionally, in the inferior wines, artificial colouring matter is added in the form of the many varieties of aniline dyes, logwood, cochineal, etc. Dr. Dupré has suggested the use of cubes of gelatin as a convenient test for distinguishing between the genuine colouring matter of wine and artificial mixtures. When gelatin cubes ½ inch square are immersed in wine for 24 hours, if the wine be pure the colour is confined to the margin, while all other colouring matters penetrate deeply into the gelatin; the only exception is rhatany root, the colouring matter of which acts like that of wine. The adulterations of wine are mainly in the direction of added spirit, artificial colouring, and "plastering" to secure clearness and dryness.

The term "dryness" as applied to wines is meant to express a flavour which is not that of sweetness. It has already been explained that the fermentation of grape juice in the formation of wine is the result of a vegetable growth—that of a microscopic fungus which the *must*, or juice of the grape, obtains spontaneously from the atmosphere. Two distinct effects follow the growth of this fungus or process of fermentation: one is, the sugar of the must or grape juice is converted into alcohol; secondly, the greater part of the albuminous or nitrogenous part of the must is consumed as food by the fungus. If left alone, the fermentation goes on until either all the sugar is used up or until the supply of sufficient albuminous matter is exhausted. Now, it will readily be understood that the relative proportions of these present determine which of the two gets exhausted first; and if the sugar is used up before the albuminous food of the fungus, a dry or not sweet wine is produced, while if the nitrogenous food is exhausted

first, the remaining unfermented sugar produces a sweet wine. Since the juice of the ripe grape contains from 10 to 30 per cent. of sugar, there is a very wide range.

A large number of people dislike sweet wines, hence the demand for what is called a dry wine. From what has been stated as to the difference in origin of a naturally sweet wine and a naturally dry wine, it will be apparent that the poorer the grape the drier the wine made from it; but the yield from a poor grape is less than that from a rich one, hence naturally dry wine costs more to produce than naturally sweet wine. It will also be apparent that the conversion of naturally sweet wines into dry ones will not be difficult, and since there is a demand for dry wines the artificial conversion is frequently performed. It is carried out either by making the wine from unripe or poor grapes, in which case the yield of alcohol and flavour are both low; or it is done by adding some nitrogenous material such as gelatin, isinglass, or white of egg to the must, so as to feed the yeast fungus until all or nearly all the sugar in the grape has been converted into alcohol. This procedure is sometimes called *fining*, in the wine trade, and is the least objectionable of all methods of artificial drying, being, as it is, almost identical with the natural cause of wine dryness. Unfortunately, there are other methods adopted which are less commendable but more common. These consist often in making an imitation of the natural dryness of wine by adding factitious salts and fortifying with alcohol. The sugar still exists as largely as before, only its taste is disguised.

Perhaps the most general method of increasing the dryness of a given wine is that of adding mineral acids and mineral salts, more particularly gypsum, or Spanish earth. This is technically known as "plastering," because gypsum is plaster of Paris. This being largely sulphate of lime modifies the chemical characters of the wine by decomposing the cream of tartar or potassium tartrate into calcium tartrate, potassium sulphate and free tartaric acid, at the same time altering the colouring matter and changing the neutral organic compounds which exist in grape juice. The use of gypsum materially clears a wine, making it look brilliant; this is explained by the fact that the resulting sulphate of potash is much more soluble than the antecedent tartrate of potash. To a certain extent, after the addition of gypsum, much of the tartaric acid of wine is replaced by sulphuric acid, a body which renders wine, so altered, distinctly unsuitable for daily use. The sherries suffer the most from plastering—so much so, that some chemists advise that the plastering of wines should be called adulteration.

The nutritive value of the wines is small, and in the main subsidiary to the stimulating properties of their contained alcohol. The clarets and lighter wines are more or less antiscorbutic, owing to the presence of the organic acids. Port and sherry appear to predispose to gout. The presence of some albuminous principle in wine may give it a slight nourishing value, but in favour of such a view the evidence is small.

Of all the alcoholic beverages, spirits contain the largest amount of alcohol. They are all made by the distillation of alcohol from the fermentation of various saccharine or starchy materials. The more common spirits in this country are brandy, whisky, rum and gin. The basis of all of them is ethylic alcohol, mixed with water; but they all contain other alcohols, usually classed together under the name of fusel oil, various compound ethers and fragrant bodies produced during distillation. It is the varying proportions of these latter which give the respective spirits their characteristic taste and aroma. After being kept for some years, spirits become mellowed or softened down; this was formerly supposed to be due to the diminution of the so-called fusel oil, but it is now more generally regarded as due to a lessening both in quantity and quality of the empyreumatic or flavouring substances.

Brandy is made by the distillation of fermented grape juice. When first distilled it is colourless, but gradually darkens with age, though too often artificially coloured by means of burnt sugar. Pure brandy consists of water, alcohol, acetic acid, acetic and œnanthic ethers, a volatile oil, colouring matter and tannin. It usually contains from 46 to 55 per cent. of alcohol. The best kinds come from France, the more inferior from Spain, Portugal, and Italy. The chief adulterations are water, cayenne pepper, burnt sugar and acetic ether. Some of the cheaper brandies are not made from grape juice at all, but are mere imitations, made from corn spirit, flavoured and coloured. According to Blyth, a very usual process of making brandy artificially in England is to add to every 100 parts of proof spirit from ½ to 1 lb. of argol, some bruised French plums, and a quart of good Cognac; the mixture is then distilled, and a little acetic ether, tannin, and burnt sugar added afterwards.

Whisky is really one of the corn spirits, being made from malted grain. The more inferior kinds are prepared from oats, barley, or rye, or from potatoes mashed up with malted barley and then roughly distilled and burnt in order to give it the peculiar smoky flavour characteristic of some varieties. Whisky usually contains from 40 to 50 per cent. of alcohol. Its adulterations are much the same as those of brandy.

N

Rum is a spirit obtained by distillation from the fermented skimmings of sugar-boilers or the drainings of sugar-barrels (molasses). Like brandy, it is colourless when first distilled, but it is later on artificially coloured with burnt sugar. Rum is chiefly made in Jamaica, and, owing to the habit there of putting a few slices of pine-apple into the best qualities, it is often flavoured with that fruit. The peculiar flavour of rum is due to butyric ether and a volatile oil; the amount of alcohol present in rum is from 50 to 60 per cent. An imitation flavouring identical with that of the Jamaica rum flavoured with pine-apple is made by distilling butter with sulphuric acid and alcohol, and then, by means of the resulting butyric compound, a factitious rum can be made from malt or molasses spirit.

Gin in this country is usually made from a mixture of malt and barley, flavoured not only with juniper berries but with oil of turpentine, orange peel, and several other aromatic substances. In Holland it is made from unmalted rye and barley malt, with juniper berries. In consequence of the juniper and turpentine contained in gin, it is a direct stimulant to the kidneys. It usually contains from 49 to 60 per cent. of alcohol. Its chief adulteration is water, which makes it turbid; to remove this, alum and acetate of lead are employed, followed by the addition of sugar and cayenne pepper to sweeten it and give it pungency. Speaking generally, gin is the spirit of which most is annually consumed by the public, and the spirit which is most often adulterated.

Unless expressly stated to be otherwise, brandy, whisky and rum are expected by law to be sold of not less alcoholic strength than 25 degrees below proof, while gin should not be less than 35 degrees under proof spirit; of course, in the other direction, or over proof, there is no limit.

CHAPTER IV.

SOILS, SITES AND BUILDINGS.

There is every reason to believe that originally our earth was in a molten state, and that in the course of ages it gradually cooled down, forming a sort of solid crust round a liquid core. After this crust of the earth, as it were, had solidified and become what we call *igneous* rock, or rock produced by the action of fire, it was subjected through long periods of time to the wearing action of rain, frost and wind, with the result that much of it was worn

down into fine particles, which, collecting together, contributed to the formation of another class, called secondary or *sedimentary* rocks.

Soils.—Now, it is of these two kinds of rocks that the great mass of the earth is composed in the present day, examples of the igneous rocks being granite, basalt, and volcanic lava, while representing the sedimentary rocks are the various sandstones, greensands, limestone, chalk, gravel and clays. The surface of the ground, or soil, is really only the result of the gradual wearing or breaking up, as it were, through many ages, of these various rocks of which our globe is mainly constituted. It is convenient to divide the soil into two parts—namely, a deeper portion, or *subsoil*, consisting chiefly of inorganic materials, the direct result of the breaking up of the rock under various agencies; and an upper portion, or *surface soil*, which, again, is derived partly from the inorganic subsoil and partly from the products of the decomposition of animal and vegetable (organic) matter.

The nature of the surface soil varies considerably in different places, consisting not only of the decayed upper surface of rocks beneath, mixed with the remains of animal and vegetable matter, but also of much alluvial deposit, or material brought by running water from neighbouring or distant districts. To this action must be added the constant transposition of soil by earthworms, ants, moles, rabbits and other animals, the general effect of which is to disintegrate the soil, riddle it with holes or burrows, and to admit air into its deeper parts.

Allusion has been made to the presence in the surface soil of the products of the changes which organic substances undergo in it. These changes, which are chiefly in the direction of oxidation, but occasionally in that of reduction, are largely the result of the action of bacteria present in the soil, these micro-organisms being much more numerous in the superficial layers than at a greater depth. The most important property possessed by soil, owing to the presence in it of micro-organisms, is that of nitrification, whereby organic matter is decomposed into its simplest constituents, so as to be readily made use of by vegetation. Plants are unable to obtain their supply of nitrogen direct from complex organic bodies, but, thanks to the action of the bacteria, these are so split up that their nitrogen becomes converted into ammonia, thence into nitrites and nitrates, in which form plants can take up their required nitrogen. Earth which has been rendered free from living bacteria, by heating or other methods of sterilization, appears to be, not only incapable of producing nitrification, but also unfit for the growth of plants. Although the greater number of the bacterial forms present in the upper soil layers are incapable

of causing disease in man, still, certain micro-organisms which are capable of producing human disease are occasionally met with in the earth. The chief of these are the bacilli of tetanus or lock-jaw, of anthrax or glanders, of enteric fever, and of a peculiar disease known as malignant œdema. The particular micro-organism associated with malaria is probably also an inhabitant of the soil, while those producing cholera and epidemic diarrhœa are not unlikely also soil residents. That micro-organisms capable of causing disease in man do exist in soil is beyond doubt, but, fortunately, their power for doing harm appears to be extremely small.

In a general sense, as influencing health, soils need to be considered not only as to the nature and number of their contained micro-organisms, but also in regard to the amount of moisture and air in them and their capacity for heat. The moisture in soil is derived from two sources—namely, from the rain, and from the subsoil water beneath. If a hole be dug in any soil, a certain spot will be reached, at a varying depth, at which all the soil interstices are full of water; that is to say, at and below this depth there is a continuous sheet of water known as *ground water*, or subsoil water. The depth at which this will be found, of course, varies in different places, being in some localities within a few inches of the surface of the ground, and in others only some ten to hundreds of feet below. Above the level of the ground water the soil is kept moist by capillary attraction and by evaporation of the water below, by rainfall and by movements of the ground water; on the other hand, the upper soil layers are constantly losing moisture by evaporation from the surface and through vegetation. When the ground water rises, it forces air out of the soil, and at the same time may pollute wells by bringing into them the washings of impure soils. When it falls again it leaves the soil, of course, moist and full of air. The variations in the movements and height of the ground water are conveniently measured by noting the water-level in wells; but, to be reliable, this needs to be done frequently and simultaneously in the wells over a large area, so as to avoid any error due to purely local conditions.

The nature of a soil will largely influence the amount of moisture which it will take up or retain, and practically there are no soils which are not capable of holding some moisture. In regard to water, all soils have two actions, namely, permeability and absorptibility. The permeability of a soil to water is practically identical with the speed at which percolation takes place through it. Observations show that water passes most slowly through clay, and with increasing swiftness through marls,

loams, limestones, chalks, coarse gravels and fine sands. Even through chalk, percolation is by no means rapid. Percolation is most rapid when soil is saturated with moisture. The amount of moisture retained by a soil depends mainly upon its absorptibility, and this being largely a result of capillary action, varies with the coarseness or fineness of the pores of the soil, and is greater for soils which consist of fine particles. Thus, granites will absorb from 0·1 to 0·4 per cent. of moisture ; slates 0·2 per cent. ; limestones 2 to 13 per cent. ; sandstones 3 to 8 per cent. ; chalks and clays 17 to 20 per cent. ; marls and loams 30 to 50 per cent. The moisture present in any soil sample is easily estimated by weighing it before and after drying, and then calculating out the difference in weight as a percentage of moisture. From results obtained by many observations, it would appear that the capacity of soils for moisture increases with the amount of organic substances present ; decomposition is most active in soils when the moisture is about 4 per cent., but can continue when it is as low as 2 per cent. ; any excess over 4 per cent. seems to retard decomposition changes in soil.

Above the level of the ground water, all soils contain air, and this is sometimes called the *ground air*, because it fills all the space not occupied by either water or solid particles. Its amount varies with the degree of looseness of the soil, some sands containing as much as 50 per cent. of air. In its composition, ground air more or less resembles that of the atmosphere above the earth ; that is to say, it contains moisture, organic matter, oxygen, nitrogen, carbonic acid and occasionally ammonia, marsh gas, sulphuretted hydrogen and other products of fermentation and decomposition. The oxygen in ground air decreases with the depth, while the carbonic acid increases with the depth below the surface. If we bear in mind the processes which are constantly going on in the soil, this is just what we might expect, because the oxygen of the air on passing into the soil combines with the carbon derived from the animal and vegetable matter present, producing large quantities of carbonic acid. The amount of nitrogen in ground air is almost constant, and usually is about the same as present in the atmosphere.

The proportion of carbonic acid in soil air increases not only with the moisture, but also with the temperature of the soil, the maximum being attained in July, and the minimum in January. The ground air, like the ground water, is constantly moving, the chief influences being wind, the percolation of rain, the rise and fall of ground water, and variations in temperature and barometric pressure. Heavy rains will not only force ground air to a deeper level, but will also force it out of the ground at places

which are dry, as, for instance, the basements of houses. The effect of variations in level of the ground water in producing corresponding movement in the ground air has already been mentioned; while probably of even greater importance are the changes in temperature and barometric pressure. The temperatures of the atmospheric and ground airs are seldom the same, with the result that there is a constant ebbing and flowing of air in and out of the soil. As illustrating these effects of different air temperatures, allusion may be made to the aspirating power which warm houses, unprovided with impermeable basements, have in drawing air up out of the ground. A case is on record in which an escape of gas took place from a pipe 20 feet under the ground; the gas smell was noticeable in houses above, although no gas was laid on to them, the same having passed through foundations, cellars and floors into the rooms above. In the same way, foul air from defective drains may contaminate houses unless an impermeable layer is placed between the house basement and the ground. Connected with this point is the idea whether the prevalent custom of covering roads and streets in our towns with stones and other impermeable materials does not favour the ground air being drawn in large and dangerous quantities from more or less polluted soils into houses, the basements of which are rarely protected by a concrete layer.

The percentage of air in a soil is best estimated by using two graduated glass burettes connected together at the bottom by a clamped tube. One burette is filled with water and the other with dried and finely powdered soil. By opening the clamp, the water will, of course, pass from one up through the soil in the other, expelling as it rises all the air in the soil. After being allowed to run in until the water just reaches the soil surface, the following calculation will give the percentage of air present in the soil:—

$$\frac{\text{Amount of water used}}{\text{Amount of dry soil used}} \times 100 = \text{percentage of air.}$$

Not only do some soils contain more moisture and air than others, but they are also more easily heated. These variations depend mainly on their looseness and colour. To a certain extent, variations in the heat of soils depend upon that of the atmosphere; the daily variations ceasing to be susceptible below 4 feet from the surface. As a general rule, it may be said that the surface soil is warmer by day and colder by night than the air; and that owing to the slow heat-conducting power of soils, the changes in the surface temperature are not felt in the subsoil until long after they have taken place at the surface, so that the

subsoil reaches its greatest and lowest temperatures later than the surface soil, and that the subsoil is colder in summer, but warmer in winter than the surface; this in turn again being in cold weather higher than that of the atmosphere, and just the reverse during hot weather. The temperature of any soil depends mainly upon its relative power for absorbing and radiating heat. The absorbing power of soils for heat varies much according to their geological formation and colour, while their radiating powers depend rather upon the kind and thickness of the vegetation growing on them.

Assuming 100 as the standard, Schübler gives the following figures as the expression of the respective powers which different soils have of retaining heat:—

Lime sand . . .	100·0	Clayey earth . . .	68·4
Pure sand . . .	95·6	Pure clay . . .	66·7
Light clay . . .	76·9	Fine chalk . . .	61·8
Gypsum . . .	72·2	Humus	49·0
Heavy clay . . .	71·1		

Sands not only warm more rapidly than other soils, but also appear to retain their heat better, while clays not only warm more slowly than sands, but lose heat more rapidly. As judged by their relative power for losing heat, soils appear to stand in the following order:—Clays, loams, marls, chalk and sands. As a rule, dark soils warm more rapidly than the light-coloured ones; and all soils usually cool more quickly than they heat, particularly when vegetation is abundant. Owing to the slowness with which water absorbs heat, all moist soils are slow to warm, and, as such, invariably constitute what are called "cold soils." At first sight, it may not appear that the temperature of the soil has any very important bearing upon health, but apart from its influence upon the various processes of either decay or oxidation going on within the soil itself, the temperature of the ground has a direct influence upon the temperature of the atmosphere and also upon many of the conditions which are implied by the word "climate." In this connection, the relative degrees of warmth or coldness, of dryness or moistness, of purity or impurity of soils are of the very greatest importance in estimating the value of any particular soil or ground as a site for dwellings or buildings.

Sites.—Although the choice of sites for our houses in towns and villages is usually sacrificed to expediency or necessity, and more often than not fixed upon regardless of the advice of any one, still, some knowledge of the chief considerations which should rule the selection of a building site is none the less necessary, because, if we ever do have a choice in the matter, it is as well that we should know how to choose, or at least understand

what to avoid, in making our selection. This question involves the following considerations :—

1. The aspect or exposure to wind, light and air.
2. The ground or soil on which it is proposed to build.
3. The surroundings of the site.

In considering the aspect of any particular site, it may be said that the brightest and most airy house is usually the healthiest; but while it is necessary that a house should be so situated that there is a free circulation of air about it, it is advisable to avoid exposure to a prevailing cold wind, and, if possible, shelter from this should be secured by means of a belt of trees or some rising ground. The door or entrance should equally be protected from the prevailing wind either by actual position or by means of some special protection, such as a porch. Every house should have, both in front and back of it, an open space at least equal in length to its own height, so as to allow sufficient light and ventilation for the rooms on the lowest floor.

In this country the living-rooms should, as far as possible, face the south and west, so as to be both bright and cheerful. The north is best allotted to working rooms and the dining-room, as twilight lasts longest there; the staircases are also best when arranged upon this side of the house, being always cool. For the larder, pantry, or dairy, this aspect is exceptionally good. Bedrooms will be found most comfortable when facing the north-east, as they get a pleasant morning sun, and are correspondingly cool at night. The east is suitable for the breakfast-room, morning-room and library, but not for the drawing-room, as it lacks the afternoon sunshine. In the south-east may be placed bedrooms, and for rooms used by the sick this aspect cannot be surpassed for fitness. The south is unsuited for dining-room windows, unless there be a good verandah; the south-west and west are not good aspects for bedrooms or dining-rooms, as, under the influence of the afternoon sun, rooms on this side of a house are apt to get unpleasantly hot. Where a bedroom is occupied only as a sleeping-room, aspect is of the least importance. By the aid of the table on p. 185, and a study of the compass, the principal points with regard to aspect and light will be readily seen.

In towns, those houses are generally the healthiest which are built in wide roads or squares permitting a free circulation of air. Narrow courts, alleys and back-to-back houses should be avoided. The evils of these latter houses have been repeatedly pointed out; in them, through ventilation is not to be obtained; their sculleries, store-rooms and pantries are nearly always ill-ventilated, dark and difficult to keep clean, while their

Window aspect.	Sunshine, March 21.		Sunshine, June 21.		Sunshine, September 21.		Sunshine, December 21.	
	Begins.	Ends.	Begins.	Ends.	Begins.	Ends.	Begins.	Ends.
East . .	6 a.m.	10.30 a.m.	Sunrise	10.30 a.m.	6 a.m.	10.30 a.m.	None.	None.
South-east	,,	1.30 p.m.	4.30 a.m.	1.30 p.m.	,,	1.30 p.m.	Sunrise.	1.30 p.m.
South . .	7.30 a.m.	4.30 ,,	7.30 ,,	4.30 ,,	7.30 a.m.	4.30 ,,	,,	Sunset.
South-west	10.30 ,,	Sunset	10.30 ,,	7.15 ,,	10.30 ,,	Sunset	10.30 a.m.	,,
West . .	1.30 p.m.	,,	1.30 p.m.	Sunset	1.30 p.m.	,,	1 p.m.	,,

closets have to be built in blocks, and are frequently, if not in an actually public position, at an inconvenient distance. The areas or basements of nearly all houses are unhealthy; being usually dark, frequently damp, ill-ventilated and rarely wholesome. Although it is important that houses should be freely open to both air and light, still the circumstances of towns and cities prevent these conditions being attained so readily as in the country. To obviate as far as possible light and ventilation being interfered with by houses being too near each other, it is now ordered in London and in the larger towns that all new streets shall be at least as wide as the houses on either side of them are high, and that no new street be less than forty feet wide.

With the same object in view, it is enacted by the Public Health Act of 1875, that no cellar built or rebuilt since 1848 can be occupied or used as a separate dwelling, and even those which existed before 1848 as separate dwellings may not be now occupied unless they comply with the following requirements. (*a*) The height must be in every part at least 7 feet, 3 feet of which must be above the level of the street. (*b*) An open area at least $2\frac{1}{2}$ feet wide in every part, and 6 inches below the floor level must extend along the whole frontage; this may be crossed by steps, but not opposite the window. (*c*) The cellar must be drained by a drain at least 1 foot below the floor. (*d*) There must be proper closet and ashpit accommodation. (*e*) There must be a fireplace and chimney. (*f*) There must be a window at least 9 square feet in area capable of opening; the window of a back cellar let or occupied along with a front one need only be 4 square feet in area. Very similar conditions are laid down for underground rooms by the Public Health (London) Act of 1891.

As regards the ground or soil on which it is proposed to build, our aim should be to secure either a naturally dry place, or one at least easily drained, and into which the drainage from

other spots does not, and is not likely to flow. For this reason, all low-lying swamps and hollows should be avoided. If the district is generally level, every advantage should be taken of any slight elevation in order that the house may be built as high as possible. If, on the other hand, it is a hilly country, the actual slopes or sides of a hill are not usually good situations for houses. No dwelling should be built close in to a hill, as it is sure to be damp, and proportionately unhealthy. It is preferable to build either on the actual top of a hill or on a terrace or spur some little way off the hill itself (Fig. 38). For similar reasons, the banks of rivers, unless well raised above the highest level of

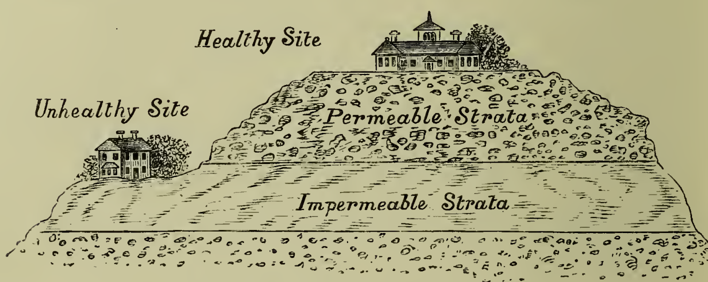


FIG. 38.—Healthy and Unhealthy Sites for a House.

the water, are to be avoided. Such localities are difficult to drain, usually very damp and liable to be flooded

Wherever possible, the soil or ground itself ought to be porous, such as gravel or sand, which allow of water running freely away, and do not cause it to collect about the house. The next best soils on which to build are rocks, such as granites, clay, slates, limestones, sandstones, or chalk; these nearly always have a good slope, and drain easily. The loams and stiff clays are not as a rule good soils for building purposes, as, unless well drained, they are apt to hold water; if, however, adequately drained, these are not necessarily unhealthy. Land drainage is effected either by means of deep drains, or by unglazed, porous earthenware pipes, placed at varying depths of from 1 to 3 feet below the soil surface, and about 6 feet apart. Pure chalk forms a healthy site, being permeable; if the chalk be mixed with clay (marl), or be underlaid by clay, it becomes impermeable and damp. If of any thickness, gravel beds make good building sites. The worst soils are the shallow beds of gravel or sand lying on clay; these are frequently waterlogged and proportionately bad; the same remark applies to reclaimed lands near the mouths of rivers, and the so-called alluvial lands, which consist of soils that are really

the deposit or sludge from rivers. Alluvial tracts are almost invariably unhealthy, owing not only to their dampness, but also to the large quantity of organic matter which they contain. These soils and sites are peculiarly liable to produce rheumatism, ague and various forms of malarial fever, as well as catarrhs and neuralgia.

In towns and modern cities, care should be taken that no artificial site be chosen, that is, one placed upon a so-called "made soil," which is really a soil made up of rubbish. The usual method for preparing such a made soil is to select a plot of ground, remove and sell the surface turf, and then dispose of the surface soil for gardens. After this, the subsoil is dug out and sold as either sand, gravel, or clay. The site is now a large pit in which rubbish of all kinds is tipped until its level is raised to a sufficient height to be regarded as a building site. Very often no preliminary excavation is made, but rubbish invited to be thrown into some natural hollow or low-lying piece of ground until completely filled up. The rubbish usually composing such soils is peculiarly rich in decomposing organic matter liable to give rise to particularly injurious products. It is certainly unsafe to build upon any such made soil until the rubbish of which it is so largely composed has been exposed to the sun and air for quite three years, and even then the dwelling built upon it should have an air-proof basement of concrete, or some impermeable material.

This concrete should be from 4 to 6 inches thick, and may, in some cases, be made to serve as a floor itself, particularly in passages, wash-houses, sculleries and pantries. If the expense of this be objected to, a layer of well-puddled clay is probably the next best thing, or, if neither of these arrangements be adopted, and a boarded-floor basement is used, a space of at least 9 inches has to be left between the under side of the floor and the ground surface, not only for ventilation and as a preservative against dry rot, but also as a means of disconnection between the soil air and the air of the house. In some places it is necessary to raise the building on arches to keep it sufficiently clear of the ground; but, in any case, there ought to be some distance between the foundations and the floor of the lowest rooms, while the space so left should be ventilated. As a rule, cellars under houses add to their healthiness, especially if properly built with an impervious flooring, and adequately ventilated.

In all sites, it is important to notice the distance of the ground water from the surface. As already explained, if this water be too near the ground-level, the spot will be damp; it ought never to be nearer the surface than 5 feet, and, if possible, should be at

least 15 or 20 feet below the ground-line. There is good reason to believe that frequent, sudden and extensive changes of water-level are specially unhealthy; therefore a place where the level of water in a well is apt to rise and fall a good deal is not a good site. These remarks apply as much to towns as to country, for often one part of a town may be less healthy than another on account of its situation being lower, and the level of the ground-water higher. Statistics for many years go to show that where the ground-water level has been lowered, and the soil made drier by means of drainage, there the public health has improved. This improvement in health has been chiefly in the lessening of such diseases as consumption, bronchitis, catarrhs, sore throats, rheumatism and ague.

In judging of the influence of surroundings upon the wholesomeness of a given site, it is necessary to assure one's self that the soil or subsoil is not being fouled by the drainage of any neighbouring building. Thus, when one house lies at a lower level than another near it, it is likely to suffer from the effects of the drainage from the one above. In cases where houses stand alone, as in rural districts, special care needs to be taken that no heaps of farm refuse or manure, cesspits, middens, or other collections of decaying matter are allowed to remain near the house. The immediate neighbourhood of sewage-farms are undesirable, as, too, are the vicinities of factories, chemical works, graveyards and marshes, the air of which districts are apt to be impure from either refuse or generated gases. The irrigation of adjoining land, as a rule, makes a site less healthy than it ought to be, especially if the irrigation be carelessly carried out, as this raises the level of the ground-water.

Summing up the facts in regard to a choice of site for building purposes, the most essential points to be sought for are as follows:—

1. A moderately elevated spot, with the ground falling away from it on all sides, sheltered from the north and east, but not so shut in as to impede the free circulation of air round and over it.

2. The site should, if possible, be upon a porous soil, such as gravel or sand, care being taken, however, to see that the subsoil is sufficiently permeable to secure thorough drainage, either naturally or artificially.

3. The ground-water should not be nearer the surface than 10 feet, and not subject to either great or sudden fluctuations.

4. The surface soil and subsoil, no matter what their nature, should be clean, and not fouled by either sewage or refuse.

Having then secured a suitable site, the next thing is to see that

the building proposed to be erected upon it is so built that it may be regarded as healthy. To that end, it must be so constructed as to be able to be kept free from damp, to be proof against weather, and to maintain the air within it pure and wholesome. These indispensable conditions, applicable equally to the private dwelling-house or to public institutions, involve attention being directed to the way in which the foundations and brickwork are arranged, to the material and state of the outer walls and roof, to those of the inside walls, ceilings and floors, as well as to the general arrangements of the building, and the means for removing excreta and refuse.

Dwelling-houses.—The foundations ought to be sufficiently solid, and deep enough in the ground to give firmness to the building. When the ground is soft, or a solid foundation cannot be reached, the walls should be built upon a solid platform of concrete or stone, which should be at least four times as broad as the walls. The bases of the walls themselves should be expanded into what are called *footings*, the lowest course of which should be at least twice the breadth of the wall. The height of the footings ought to be not less than two-thirds of the wall thickness.

The situation and nature of the soil may need measures to be taken to prevent damp rising in the walls by capillary attraction, and in order to do this it is necessary to lay a *damp-proof course* along the full thickness of the wall above the highest point at which the wall is in contact with the earth, and below the lowest timbers or floor supports. This course is either made of glazed tile, slate, or sheet lead, asphalte or other impervious material. The walls of no room or cellar should be in direct contact with the soil. This can usually be secured by digging away the earth on the outside to below the level of the floor, so as to form a "dry area." As an alternative plan to this, a device recommended by the Local Government Board in their Model Byelaws may be employed; this consists in making the wall hollow up to a point above the ground-level, and then inserting two damp-proof courses, one at the bottom of the hollow and below the floor-level, the other at the top of the hollow, and therefore above the outside ground-level. By this means the inner wall is quite shut off from the soil. Both these arrangements are shown in the diagram (Fig. 39).

The materials ordinarily used for the construction of the walls of dwelling-houses are bricks, stones and wood. In many tropical countries crude, or sun-dried bricks are employed, but these are unsuited for this climate, and we have therefore to do with baked or kiln-dried bricks. Bricks are made from three kinds of earth,

namely, pure clays, marls and loams. Pure clay consists chiefly of alumina and silica; marls are clays having in addition a considerable amount of lime in them; while the loams are light or sandy clays. Few bricks are made solely from any one of these earths, but rather from an admixture of all three. A good brick should be regular in shape, of a uniform colour, well-burnt, and, when struck, give a clear, metallic ring. Ordinary bricks weigh about 7 lbs., and are $8\frac{3}{4}$ inches long, $4\frac{1}{4}$ inches broad, and $2\frac{3}{4}$ inches thick, giving a total bulk of about 102 cubic inches. They are porous, and readily absorb water, usually from $\frac{1}{5}$ to $\frac{1}{7}$ of their bulk, or say a pint of water. So porous are bricks that both rain and air can be easily driven through them; in fact, so much is

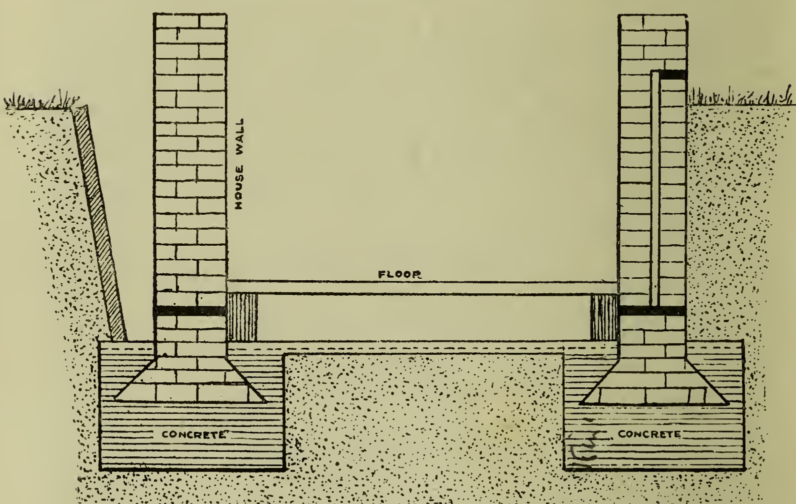


FIG. 39.—Diagram showing placing of damp proof courses.

this the case that it is desirable in all dwellings that the outer walls should, if of brickwork, be at least a brick and a half thick (14 inches), so that in addition to the bricks, there may be in the structure of the wall itself a vertical layer of mortar. Mortar is a compound of 1 part of lime with 3 parts of fine clean sand, made up with fresh water; if salt water be used, the mortar dries badly. Owing to bricks having already, during manufacture, been burnt, they stand fire better than anything else, and on this account are superior to any other material for house walls.

Two classes of stone are ordinarily employed for house building: they are sandstone and limestone. Sandstone has been

described as sand made into a cake with clay, lime and oxide of iron. It is the varying amount of this latter which gives the various colours to it, such as red, yellow and grey sandstone. Limestone is a rock composed mainly of carbonate of lime. Like bricks, stone is both porous and absorbent of water, but in a less degree.

Wood is only occasionally used in the external walls of houses in this country, but enters largely into the construction of the inner fittings of all dwellings. In its natural state it is extremely absorbent, and the unavoidable cracks and crevices admit both air and water. The chief kinds used are ash, beech, oak, elm, pine and larch. The first four differ from the latter two in being free from turpentine. Good timber should be close and straight grained, free from cracks and dead knots, and well seasoned.

The *walls* of all dwelling-houses should be most carefully built from the foundations upwards, whether of brick or stone, with a layer of mortar not only between each course, but under the first course, and, too, well fitted into the vertical joints. Bricks are laid in beds or courses, and are usually spoken of as being

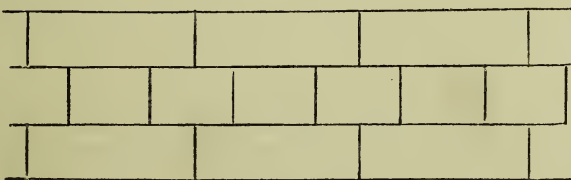


FIG. 40.—English bond.

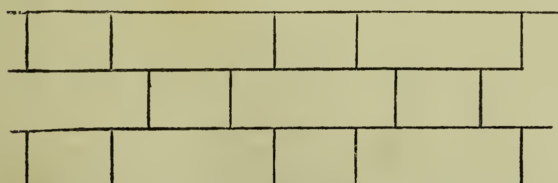


FIG. 41.—Flemish bond.

bonded together. There are two ways of laying bricks, called respectively English and Flemish bond. The English bond is a course of bricks each showing one side alternating with a course in which each shows an end (Fig. 40). Flemish bond is a single course of bricks in which they alternately show a side and an end (Fig. 41). The former method is considered to be the stronger. The thickness of the outer walls of dwelling-houses is determined

by the size of the building, more particularly by its height. According to the Model Byelaws of the Local Government Board, the minimum thickness should be as follows:—Where a wall is not over 25 feet in height, if it does not exceed 35 feet in length, and does not comprise more than two stories, it shall be 9 inches for its whole height, but if it does comprise more than two stories, or exceed 35 feet in length, it shall be $13\frac{1}{2}$ inches below the topmost story, and 9 inches for the rest. Where walls are over 25 feet high, and not exceeding 35 feet in length, they should be $13\frac{1}{2}$ inches thick below the topmost story, and 9 inches for the rest; but if they be longer than 35 feet, then they must be 18 inches thick for the height of one story, then $13\frac{1}{2}$ inches thick for the rest of the height below the topmost story, and 9 inches thick for the rest of its height. Walls over 35 feet high must be 18 inches thick for the first two stories, and $13\frac{1}{2}$ inches for the rest. If over 50 feet in height, walls should be 22 inches thick for the height of one story, then 18 inches for the next two stories, and finally $13\frac{1}{2}$ for the rest of the height.

Walls built of cut stone need to be no thicker than those of brick, but if of rough stone or flint and boulders, they should be at least one-third thicker. Combination walls made of both brick and stone are not uncommon; the chief point about them is the need of careful bonding together of the two elements. Occasionally walls are made of concrete either rammed down in layers or else built of concrete blocks well cemented together. Wood is at times used in making the upper part of the outer walls of houses; when so employed, it needs to be backed with at least $4\frac{1}{2}$ inches of brickwork, and well bonded together.

Owing to the absorbent and porous nature of all these materials, special care needs to be taken that outer walls constructed of them do not admit damp sideways, especially when in positions much exposed to driven rain and wind. To prevent this, they may be hung over with slate on the outer side, covered with glazed tiles, painted planks, plastered, or cemented. A surface of mortar sprinkled with small stones is occasionally employed. All these are good plans, provided they are done when the bricks are dry, as otherwise the moisture is kept in the bricks. Painting the outside of a wall with silicate, or some indestructible paint, affords a similar protection, but, like the others, interferes with the insensible ventilation or diffusion of air which so constantly goes on through the walls of most inhabited buildings. Probably the best plan to keep damp from coming through outer walls, is to build them double, with a cavity or space 2 or 3 inches wide between the inner and outer walls, and to join the two portions of such a wall together by means of *bonding-ties* of some non-absorbent

material, such as iron or glazed tiles. These bonding-plates between the two walls should slope downwards and outwards, otherwise the wet will pass across them to the inner side. In very exposed positions, it may be necessary to place within the wall a vertical damp-proof course of iron or slate. A damp-proof course is needed at the top of exposed walls, such as parapets and chimneys; this is usually provided by finishing the top of the wall either with a stone and letting it project an inch or two over the side, or by having an impervious damp-course laid in the wall or chimney at its junction with the roof. During the building of house walls, care should be taken that chimney flues are properly constructed. They should all be made as straight as possible, and separate one from another. They should contain no woodwork, and if possible be lined with pipes, an arrangement which not only disconnects the flue from the house structure, but favours cleansing and the maintenance of an up-draught. All chimneys should be higher than surrounding buildings, so that they may be in no way sheltered when the wind is in a certain direction, nor a down-draught set up.

Roofs themselves need to be closely considered, as defects in them are a frequent source of dampness. The more common materials used in making roofs are slates and tiles, or less often thatch, wood, zinc and corrugated iron. Slates when good, should be hard, free from streaks or flaws, and give a metallic ring when struck; if of poor quality, they are apt to scale and readily break away. Tiles, like bricks, are made from clay, but need more careful drying and burning. Thatch forms a good roof, being both warm and dry, but is apt to catch on fire, and, unless well looked after, is rapidly infested and destroyed by birds and vermin. Wood, covered with tarred felt or canvas, makes an excellent roofing; but, like zinc and corrugated iron, is practically only suited for temporary buildings, and is not adapted for dwelling houses. Lead is too costly to be used, other than for special parts of the roof. In all roofings, it is important to see that there is a framework, sufficiently strong to bear the weight of the material, *plus* a certain amount of snow. The framework is usually made of wood. If the covering is to be of slates, the slope of the roof should be 25°, if of tiles, at least 30°; metal roofs may be made flatter. House roofs should always be covered with boarding laid at right angles to the rafters of the framework, and, if possible, with a layer of some good non-conducting material such as felt, which not only makes the house cooler in summer, but warmer in winter. Laths are occasionally substituted for boards in roofs; this should not be, as they are much less satisfactory. When slates are used,

they should be fastened to the boards with copper or zinc nails, (not iron), and made to overlap the row below them by quite 2 inches. Tiles are often fastened with wooden pegs, or hung on by two special projections. Lead, zinc and iron roofs are laid nearly flat in widths, with their edges overlapping, to allow for expansion and contraction. In some parts of the country, flat stones are used for roofing, as in the sandstone districts. These roofs are very heavy, and extremely difficult to make water-tight. The gutters round chimneys or party walls, where they join the roof, are frequent places for leaks; they all should be made of lead, the edges of which should be well-fixed into the brickwork; cement should never be employed for this purpose, as it readily cracks. In all cases, the eaves of a roof ought to come out some distance beyond the walls, and be provided with a good gutter, so as to throw off the rain well away from the house. These gutters should be of iron, and at least 2 inches from the wall, discharging into rain pipes, which should also be of iron, and placed well outside, and away from the house wall. These rain-water pipes should either discharge into properly ventilated rain-water tanks, or over a drain covered by a grating. They should never be directly connected with drains or sewers, neither should they be placed with their heads just below bedroom windows, more particularly when they empty into a tank.

So far we have considered how to keep the outside walls of the house dry, or at least how to prevent the damp reaching the inside. It is now necessary to consider the inside walls, ceilings and floors. The inner walls of a house need to be protected and covered in some way, though some people object to it on the ground that it interferes with the porosity of the walls, and so impedes ventilation. In this climate, however, some wall covering is more or less of a necessity. The simplest is white-washing. This plan, however, is not good, as it does not do away with the porosity of the brick, and, moreover, leaves a comparatively rough surface for dirt to lodge and collect. If walls are white-washed, the wash must be frequently renewed. The best plan is to aim at securing, not only an impervious material, but one which has a smooth surface and can be readily cleaned. For this purpose, two plans can be employed; either cover the walls with glazed tiles, or plaster them and then paint with some form of indestructible paint. Papering walls is very common, but it has the disadvantage that, unless varnished, it cannot be washed, and much dirt sticks. The flock papers and their cheap imitations are particular offenders in these respects. Lime-washing is preferable to common unglazed or flock papers; but it must be borne in mind that the mere putting on of a fresh

coat of lime-wash over an old and dirty one is not cleanliness; the wall should be first scraped, and the old coat thoroughly removed. Similar objections exist to the too frequent habit of pasting new wall-papers over old. This often goes on for times together, until half a dozen or more papers are found one under the other. Each of these will have taken up its share of dirt, and each will have been laid on with a fresh supply of paste, so that, on the slightest dampness, the whole has every facility for rotting and fermenting. In all cases, the old paper should be scraped off before the new one is put on.

Ceilings are mostly made of plaster worked on to laths, fixed beneath the floor of a room above, and then either painted, distempered with colour wash, white-washed, or else covered with paper. The only advantage of the lath-and-plaster ceiling appears to be its power of deadening sound. It is probable that for health reasons it would be much better if ceilings were made wholly of wood, but in that case, to deaden sound, they might advantageously be backed by either silicated felt, or silicated cotton, and to avoid dust coming through from floors above, have the wood panelled and all joints accurately tongued and groved.

Like wall coverings, *Floors* are best made of impervious materials, which can be washed. Wood, stone, or tile, constitute the chief. Stones or tiles are very good for sculleries and passages, but are apt to be cold for kitchens and living-rooms. Wood makes the best flooring, particularly if of hard wood, such as oak or teak laid as parquet flooring. These, however, are very expensive; the ordinary wood floor being usually made with deal. In the majority of cases, floors are badly constructed, ill-seasoned wood being used, which soon shrinks and gapes. Even if made of deal, a floor can be well laid down, if care be taken to tongue and groove the planks which constitute it, or if this be not done, to caulk the seams with tow and then varnish the whole over. This will permit of its being cleaned by dry scrubbing or sweeping, and, even if washed, of being quickly dried. Too often, owing to the cracks and crevices in floors, the enclosed space below, between it and the ceiling of the next room, becomes a huge receptacle for dirt of all kinds. As already explained, if the floor be a basement one, and unprotected by concrete or other impermeable layer, or be over an unventilated cellar, foul gases and air find a ready entrance into the room. The necessity for the free ventilation of all closed spaces has been explained, and nowhere is it more needed than in those below basement floors. If the ventilation is insufficient, the air becomes damp, and a fungus growth called dry rot is liable to set in and

destroy the flooring. In the upper stories, however, the ventilation through the boards and ceiling is usually sufficient, unless constantly covered with oil-cloth or some other air-tight material. The skirtings round rooms or floors should, when possible, be of tiles or cement, but if of wood they ought to be let into a groove in the floor, a device which will serve to prevent draughts coming through, and the accumulation of dust in the holes or cracks, which are invariably formed by the shrinking of the joints and skirtings. If floors were made better, so as to insure a more or less uniform and impervious surface without cracks, or badly made joints, through which draughts can enter and dust collect, there would be less inducement to cover the whole floor area with a carpet or drugget as is so commonly done. If carpets are used, they should be sufficiently limited in size, as to leave a border of bare flooring round the room. This arrangement does not allow dust to accumulate readily in corners, and at the same time simplifies the taking up and beating of the carpet.

Having chosen a site, and entered into some detail as to the building and construction of the dwelling-house, it remains to consider the chief points as to its design and arrangement. In all efforts to plan a house, the great object is to make every use of the whole space, in order to get as much accommodation and comfort as possible. When we have to consider small cottages there is seldom much choice in the matter. In no case, however, should privies, middens, or pigstyes, etc., abut upon or form part of a dwelling-house; neither ought houses to be built back to back. If possible, rows of houses should run north and south, and all square buildings should have angles in those directions, so as to get some sunlight in every room. In dealing with houses of a better class, there are several points which call for notice. One of the most frequent errors is the cramped space allowed for halls and staircase. Plenty of space should be given for them, as with ventilating windows at the top they constitute the central ventilation of the house. All the rooms ought to be so placed as to get light and air directly from the outside; and if there be any passages or lobbies they should be similarly lighted and aired. No room or closet which has, so to speak, a borrowed light, and is not in direct communication with the outer air ought to be used as a sleeping-room. Equally it is undesirable to use a kitchen or room in which food is prepared or kept as a sleeping-room. The size and allotment of rooms will of course depend upon questions of cost, convenience and the purpose for which they are intended. The kitchens and larder ought to be on the cool side of the house, which we have already explained is in this country the north side. Some people have proposed that the kitchen should be put at the

top of the house, so as to allow smells and vapours of cooking to rise into the air instead of into the house, as when the kitchen is in the basement. Theoretically, this is a very good plan, but practically only possible in a very limited number of houses. Its general adoption, particularly in small houses, would be impossible.

The height of rooms should not be less than 9 feet, and rarely need exceed 12 feet. Every room should have at least one window in it which opens to the outer air direct; if possible it should open half its size, extending nearly to the top of the room and equal in area to at least one-tenth of the floor space. Among other requirements in a good window it should be so made as to permit of being cleaned by a person standing inside the room, whereby the risk and expense of cleaning from without are avoided. This involves the abandonment of the sash window and the adoption of one so divided that one-half vertically, or in large windows one-third, may open inwards on hinges, the other half or two-thirds being fixed and wind-tight, the breadth of each division to be such that a servant's arm can reach out and clean the outer side of the fixed window when standing inside the room. The use of skylights in the place of proper windows is not permissible. In addition, every habitable room must have either a fireplace or some special ventilating aperture or air-shaft, the sectional area of which should be not less than 100 square inches.

In the chapter on "Ventilation" allusion has been made to the various and best means of warming the dwelling. A few remarks here may not be inappropriate, relating to gas pipes, water-service pipes, and hot-water supply arrangements. Very few houses now are without a gas supply, simply because it is relatively both cheaper and more convenient than lighting by candles or oil lamps. Few people have a choice as to the source of their gas supply. In general terms, it may be described as a mixture of carburetted hydrogen with various other hydrocarbons distilled from coal in retorts, and, after purification, delivered by public companies to individual tenements. Every house supplied with gas has a meter, or arrangement for measuring the amount supplied. This meter should always be a dry one, as what are called wet meters contain water, and this being liable to freeze in cold weather may cut the supply of gas off altogether. Owing to gas being always stored in the gasometers over water, it readily absorbs it and rapidly deposits it again when reduced in temperature. The result of this is, all gas tends to deposit moisture in the pipes which deliver it. This naturally collects in the lowest sections, and the gas can only get through it in bubbles, causing

the well-known flickering of the flame. During frost, this may form a solid and impermeable obstruction. To obviate this, and prevent water lodging, a small pipe should be connected with the lowest part of the domestic service and fitted with a tap to draw off any collection of water. Supervision is needed to see that gas pipes are not hidden in walls or behind woodwork, where nails are liable to be driven in and puncture them. Care needs to be taken to see that all joints and fittings do not leak, as any such defects are a fruitful source of gas explosions, besides which there is reason to believe that the escape of minute quantities of gas from defective fittings, especially in bedrooms, often causes headache, sore throat and other conditions of ill-health. The sliding gasaliers and pendants are all sealed with water traps; these require to be systematically refilled to prevent their running dry and so allowing gas to escape. The placing of a little oil on the top of the water after having filled the tube will commonly prevent loss of water by evaporation. Too much care cannot be given to the choice of a good burner; the relative value and effect of some of them has already been referred to on p. 23. The regulation of gas pressure may be arranged by a governor to each burner; but, as a rule, this is unnecessary, as one governor or simple contrivance for regulating the gas pressure is commonly attached to the main pipe after passing through the meter, and quite suffices to secure a steady flame with no waste. An excellent example of these governors is Stott's gas valve, which, from its compactness, steadiness and sensitiveness to pressure changes, affords the individual consumer full control over his gas supply.

In the chapter dealing with "Water and Water Supply," reference has been made to the materials of which pipes are made. Dealing as this chapter does with the construction of the house itself, it is important to remember that, in planning or building a house, the greatest care should be taken to see that water supply pipes are not so placed as to be readily affected by frost. All outside walls should be avoided if possible; if necessity compels pipes to be exposed, they should be surrounded with casings of sawdust or wrapped up in felt. Branch pipes should be as few and short as possible, and made to go off at an acute angle in the direction of the flow. Cold water should be available, and laid on to sinks in the kitchen and scullery, to the bath-room—if such exist—also to the cistern for flushing closets, and in cases where no constant supply is laid on, to a separate storage cistern. It is usually convenient when a house is in connection with a public supply to have the water delivered in the kitchen and scullery direct from the main; a similar supply from the main should, if possible,

be delivered to the upper floors. In the best houses now, all taps which deliver water from the mains are marked "main," while those which yield water from cisterns are marked "cistern." This detail ensures greater care in the placing of fresh water in bedroom bottles, and avoids the issuing indiscriminately of stored

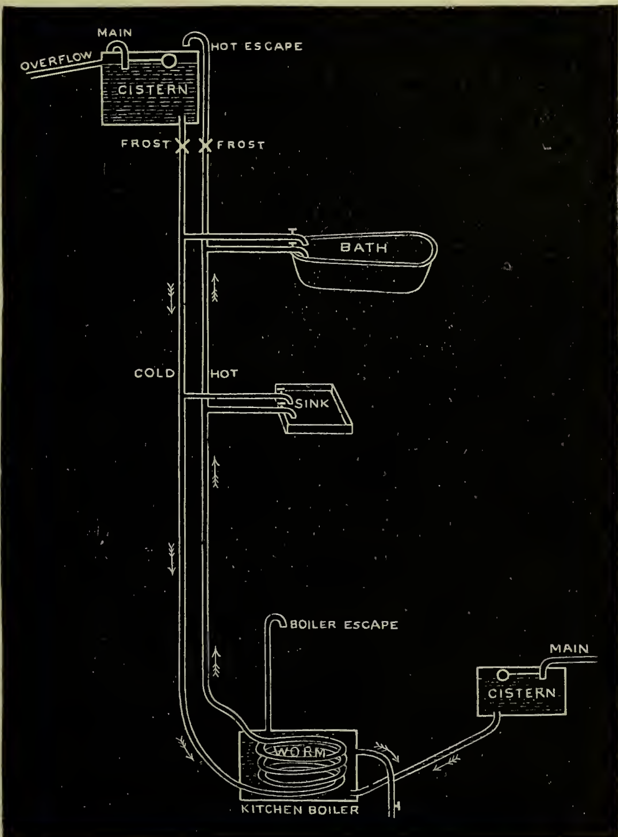


FIG. 42.—The worm boiler hot-water apparatus.

water, it may be rain water, from cisterns for both washing and drinking purposes. Whenever possible the use of storage cisterns for water should be avoided. Most water companies take care to lay their supply pipes deep enough in the soil (2 feet) to protect them from freezing; such pipes should be fitted with a stopcock or valve for cutting off the water during emergencies such as

leaks or frosts. Where pipes run horizontally, care should be taken to see that they are laid on continuous supports, and at a slope sufficient to run off their contained water when it is required to empty them. When pipes run vertically they are best fastened to wood rather than to a wall.

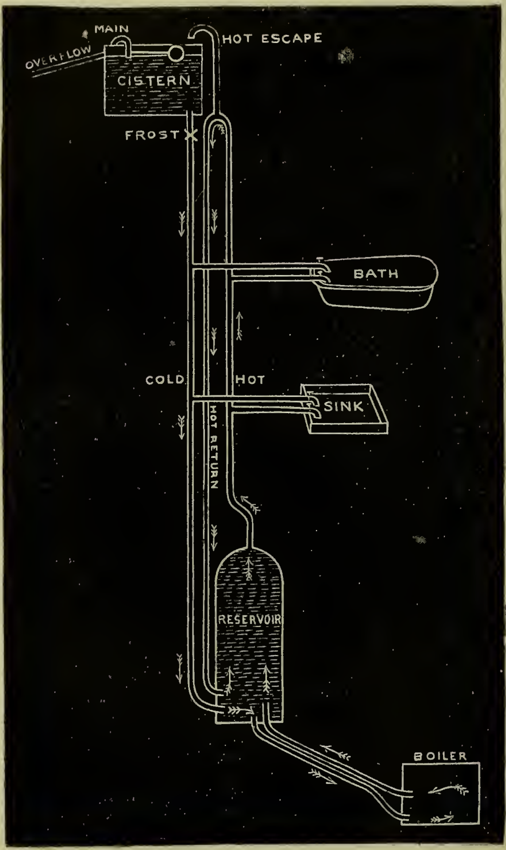


FIG. 43.—The reservoir hot-water apparatus.

Hot-water Supplies.—Most modern houses, excepting the smallest, are fitted with a hot-water supply, and this, unless skilfully devised and efficiently constructed, is likely to have unexpected consequences of a serious nature under any unusual stress, such as may be brought about by a frost of exceptional severity. The earliest form of hot-water supply was that known as the worm-boiler system. This is still occasionally met with, is safe provided the supply of water in the boiler is attended to, but not very satisfactory for getting hot water, as the hot supply for the kitchen being drawn from the boiler itself and not from the worm system, if much hot water be taken from the boiler in the kitchen, the hot supply to the rest of the house is cooled down (Fig. 42). On the other hand, it is safe, as the little feed cistern for the boiler is too near the kitchen to freeze, and so long as there is water in that so will there be water in the boiler. Even if the pipes of the worm

system freeze, no explosion will follow, as the heat, being derived from water, is never sufficient.

Of more modern methods there are two, namely, one with a reservoir and one without. The so-called reservoir hot-water service is shown in Fig. 43, and is a very effective arrangement. Its essential feature is the introduction of a metallic reservoir, usually of copper or galvanized iron, capable of bearing a pressure of 20 lbs. to the square inch, and placed between the cold and hot supply so that its contained water is heated by circulation from the boiler. This circulation of water through the system is maintained by the fact that hot water being lighter than cold escapes or ascends through the pipes in the top, and having given up some of its heat above, returns cooled by the lower pipe. The danger during frost for this apparatus exists in the possibility of both the supply and escape pipes getting frozen, in which case the water in the reservoir might get to a rapid boil without the plug of ice in the hot escape being thawed. This is largely theoretical and rarely likely to happen with hot circulating water so near. A greater danger exists if the supply pipe gets frozen and be undetected, in which case the boiler and reservoir after some length of time might boil dry, but before this could occur there would certainly be signs of unusually vigorous boiling going on in the reservoir to suggest that something was wrong.

An inferior and dangerous hot-water apparatus is shown in Fig. 44. It consists of a plain boiler at the back of the kitchen fire, having a cold feed-pipe entering its bottom from a supply cistern placed at the top of the house. From the top of the boiler runs a hot supply pipe which goes to various parts of the house, and ends as an open escape pipe over the top of the cistern. So long as it is in good working order, this arrangement is efficient, but during frost both pipes are apt to get frozen and blocked at X X simply because they are usually near the roof and exposed to cold. If the fire be lit and the water boil, no steam can escape by either pipe, the result being an explosion. Sometimes instead of both pipes getting frozen only the cold feed to or from the cistern is blocked. In a while the water that was previously in the boiler boils away, the boiler itself gets red hot, and if suddenly the cold supply be renewed or let in, the cold water rushing into a red-hot boiler gets so rapidly converted into steam that a violent explosion follows.

To meet dangers and difficulties of this kind in connection with frosts several proposals have been suggested. The best and most effective measure to adopt when a frost is anticipated, is undoubtedly to run off all water out of the system and shut off

the supply from the main over night, taking care of course to see that the supply is renewed before the fires are lighted again in the morning. Unfortunately this is difficult to always put into practice. Others have suggested that taps should be left running in order to prevent the freezing of the water in the pipes. This practice is illegal, inasmuch as it causes a waste of water and renders the householder liable to penalties; moreover, if extensively practised in low-lying districts, would automatically cut off the supply to higher districts. Probably next to emptying the pipes completely and disconnecting them from the main during the night time, the better plan in all cases, where kitchen boilers are used for furnishing hot water on a high-pressure system, is to arrange a storage cistern, sufficient to contain forty-eight hours' consumption in a protected position above the highest draw-off tap; while all pipes supplying the boiler ought to be so protected as to absolutely prevent freezing in the most severe weather. For absolute security, it is recommended that a safety-valve should be fitted to every kitchen boiler; of these, none are so simple or reliable as those of dead weight construction without either guide, spindle, or wing, so that there is no fear of their sticking fast. The safety-valve should be fixed as near the boiler as possible, the connecting pipe not being more than six inches in length. It should be enclosed in a small cast-iron box with a hinged door so as to be protected from injury, and at the same time admit of being examined whenever necessary. To see that the pipe connecting the boiler with the valve is open, the valve should be occasionally lifted, and if the water squirts out it will

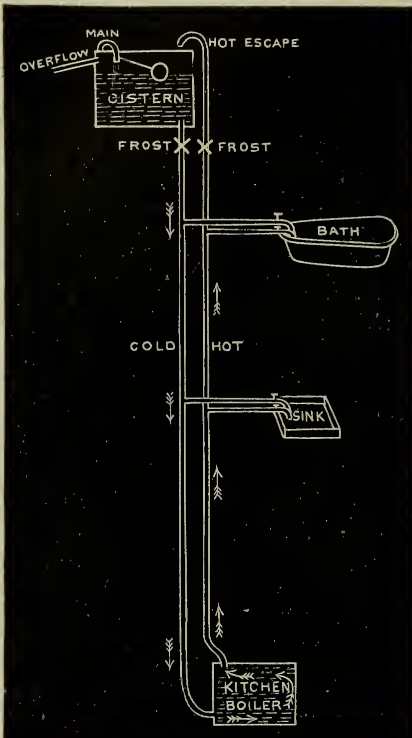


Fig. 44.—A dangerous hot-water apparatus.

show that this is so. Such valves can be fitted at trifling cost, will wear for years, and at the same time afford full and reasonable security against the undue accumulation of steam pressure within the boiler.

Any noise occurring in connection with a hot-water service is usually due to air in the pipes, or deposit choking some pipe. It may be a warning of danger and should invariably be inquired into. Owing to their fouling or furring inside from hard waters, boilers need to be cleaned out periodically. These internal incrustations may be a cause of a boiler not heating readily, but more often this defect is due to foul flues, the result of neglect on the part of servants. If the flues be foul, naturally the up-draught is lessened in them. All hot-water pipes should be allowed plenty of room for expansion and contraction.

Artisan Dwellings.—The agricultural labourer's cottage should at least comprise a living-room with small scullery attached and sufficient bedroom accommodation, say one room for the parents and two for the children. The most economical arrangement for this amount of accommodation is in a two-storied building, the height of the lower story of which should be 9 feet and that of the upper not less than 8 feet. The living-room ought to have a minimum floor area of 150 square feet and be fitted with a cupboard for storing food, lighted and ventilated by a separate window. The scullery adjoining the living-room should be 10 feet by 7½ feet, and if possible, a pantry entered through the scullery, light, cool, airy and, above all things, dry. The parents' bedroom ought to have about 80 feet of floor area, and those for the children 50 feet; all the rooms should have fireplaces in them. The privy accommodation and places for deposit of refuse are in these houses best placed in a shed out of doors. The distance at which this is placed should not be excessive, neither should groups of closets common to two or more houses be placed in yards in which children play, women hang out their washing, or men and boys loiter. Such arrangements are objectionable not only on account of decency and morals but also as tending to deter inhabitants from using the closet as freely as might be desired; as well as offering unnecessary facilities for the spread of infectious disease present in any one dwelling to the inhabitants of the others, through the medium of these privies and ashpits.

The dwelling of the town-living artisan offers greater difficulties in arrangement, because it is usually necessary to place it upon sites where land is expensive and limited in extent. The separate houses as usually built in rows should differ little from the standard just given for the country labourer with a family; but the modern blocks of artisan dwellings occasionally

present unnecessarily objectionable features. Some of the earlier built dwellings of this class were arranged on both sides of a main corridor 8 feet wide in each story. This corridor arrangement besides conducing to want of privacy and independence, involved much difficulty in regard to both light and ventilation. A further defect in some of these blocks is the provision of a water-closet as an integral part of each dwelling, and too often so placed as to be a source of danger to health. The corridors should be dispensed with and each dwelling be made independent of its neighbour for air by having vertical series of dwellings only on each side of one or more staircases, the other side of the dwellings being open to the outer air. The water-closet accommodation should be improved by rendering it accessible from each dwelling from the external air by means of some sort of covered way or balcony; while, by wholly detaching the blocks of buildings, confined angles and stagnant corners will be obviated.

In the better class of house, one of the most frequent errors is the position of the water-closet, which is often close to the bedrooms or even kitchens, and not in the least disassociated from them. Sometimes the water-closet opens out of a bedroom, often with no communication with the outer air, or at most, ventilated into a passage or hall. The proper situation for a water-closet is in a separate or outstanding part of the house, and where there are several water-closets these ought to be built one over the other, and quite confined to one part of the building. Some authorities go so far as to suggest that every closet should be cut off from the rest of the house by close-fitting doors and a well-ventilated lobby. These arrangements, however, for the separation and isolation of closets would be and probably are unnecessary, if the closets themselves are of the best construction and efficiently disconnected from the drains. Unfortunately this condition is not always the case, hence the need of some general arrangement as explained above.

Each closet ought to have at least one window of a minimum superficial area of two square feet opening direct into the outer air, also have a second opening, such as either a Tobin tube or a ventilating brick, so as to secure a circulation of the air independently of the house. The closet walls ought to be covered with glazed tiles, painted plaster or varnished paper, the ceiling too ought to be varnished or painted. The floor may be of tile or cement, or if of wood, well caulked and varnished.

The details relating to the removal of both liquid and solid refuse and excreta from houses are discussed in the next chapter; but, dealing as this chapter does with the habitation itself, it is here necessary to consider what arrangements are needed to

receive the excreta and refuse before they pass into the proper channels of removal. These arrangements usually comprise the ordinary water-closets, sinks and baths, slop-closets, trough-closets, privies of various kinds, dry-earth closets, ashpits and dustbins. The closet apparatus itself ought to be the simplest that can be obtained consistent with efficiency, and as a rule it may be stated that the more complicated the arrangement, the less likely is it to be either efficient or perfect. The question of the precise kind of closet to be adopted, whether on the water principle or on some dry principle, is dependent mainly upon the special circumstances of the place.

Closets based upon a water system for the carrying away of excrement are practically of three kinds, namely, (*a*) the ordinary indoor water-closet as found in the majority of the better class houses; (*b*) slop closets, or those in which the excrement is washed away down the drain by the waste liquids of the household instead of by clean water supplied for that purpose; (*c*) trough closets, or those connected with a trough containing water, and common to two or more seats, such as are met with in schools, factories, and other places of common resort.

Water-closets.—It is probable that there is nothing more satisfactory than a good water-closet properly connected with a well-ventilated sewer; but unfortunately such are not universally present in houses. The essential features of a good water-closet are, a basin of some non-absorbent material and of such a shape and capacity, as will contain sufficient water as to allow the excreta to fall direct into the water in the basin without touching the sides. There may be said to be five distinct types of water-closet now in general use; they are, the *pan* or *container closet*, the *long hopper*, the *valve* or *plug closet*, the *wash-out closet*, and the *short hopper* or *wash-down closet*.

The first two of these, now generally recognized as being distinctly bad forms of water-closet, are getting so rapidly replaced by better kinds that soon they will become historical curiosities. The pan or container closet is the most objectionable, and is now prohibited by the model bye-laws of the Local Government Board to be fixed in any new water-closet. Its peculiar feature is the presence of a metal container or pan, which not only rapidly fouls and wears out, but which each time the basin is emptied allows foul air to escape. Very commonly associated with this kind of closet is a D-trap, a contrivance primarily intended, by means of the water which remains in it, to prevent the return and escape of sewer gas back into the house, but which more often becomes filthy by the retention of a large amount of offensive matter. A diagram of this closet is shown

in Fig. 45. The long hopper is nothing more than a deep conical basin ending in a bent tube or syphon trap, and which from its shape and construction is extremely liable to become filthy by fouling of its sides. The valve or plug closet (Fig. 46) was a distinct improvement on the two preceding forms; but in recent years has been quite superseded by other and better kinds. Its chief faults were that it was complicated, its plug or valve often leaked, and failed to keep a supply of water always in the basin, while at the same time it was frequently difficult to keep clean; another defect was that, if by chance the syphon trap became unsealed, foul air could escape up into the house from the soil pipe through the overflow pipe.

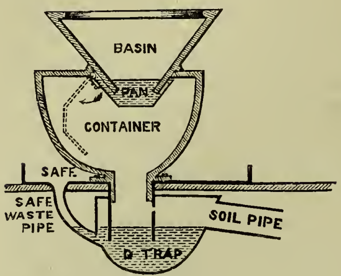


FIG. 45.—Pan closet.

Of the modern forms of water-closet, the best kinds are the wash-out, and the short hopper or wash-down closets. Both of them are entirely made out of a single piece of glazed earthenware, or at most of two pieces cemented together, and present a minimum amount of surface between the basin and the trap. In the wash-out closet (Fig. 47), a certain amount of water is kept in the basin by means of a dam or ridge, over which the excreta are carried by a flush of water. In some varieties of this closet, the ridge is made too high, with the result that, unless the flush be

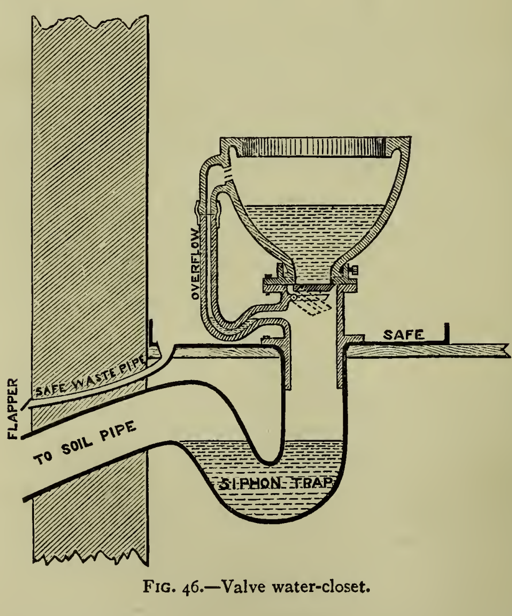


FIG. 46.—Valve water-closet.

good, the contents are not at once carried away. Of the short hopper or wash-down class (Fig. 48), one of the best is the "Deluge," which, like all good closets, should be and is pro-

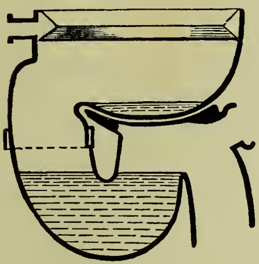


FIG. 47.—"Wash-out" closet.

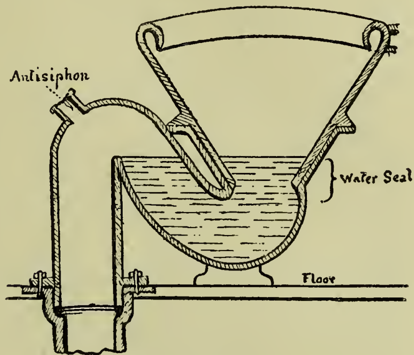


FIG. 48.—"Wash-down" closet.

vided with a flushing rim, from which the water flows in such a manner and direction that the basin is kept constantly clean. The quantity of this flushing water available should be at least 3 gallons, and to avoid waste should not exceed $3\frac{1}{2}$ gallons. It should be delivered by a $1\frac{1}{4}$ inch pipe from a height of 5 to 6 feet to secure sufficient force for properly washing out the basin. This flushing water for the closets should be supplied from its own separate cistern, and not from a cistern or service pipe which supplies water for general household purposes. Numerous instances are known, showing that outbreaks of disease, such as sore throats and enteric fever, have resulted from supplying water-closets with water direct from mains or from cisterns common to all the needs of a house; the special danger or risk lying in the fact that foul air from the closet basin tends to escape up the usually empty delivery pipe and be absorbed by the water in the cistern. The cisterns for the storage of water for closets are usually of iron, fitted with a ball-cock and valve to regulate the admission of water from the main supply, and provided with an overflow pipe. This overflow pipe should discharge direct through the wall into the outer air a few inches from the brick work; it should under no circumstances be allowed to discharge into any pipe connected with closets. In cases where water-closets are placed in the upper floors of houses, a lead tray is frequently found placed beneath the apparatus to prevent any overflow from the closet in case of leakage from soaking into the floor and through the ceiling below. This tray is commonly

called a "safe," and is of course provided with a waste or overflow pipe carried straight through the wall to end in the open air, and in no way connected with any part of the water-closet apparatus. The placing of a "safe" beneath a closet was frequently needed when the closets used were the old pan and valve water-closets; with the more modern and simpler arrangements the need does not exist, while, too, the old custom of boxing in the apparatus by means of woodwork is now regarded as unnecessary and more or less uncleanly.

The contents of a water-closet should be at once conveyed by a suitable pipe called a soil-pipe, not less than 4 inches in diameter, in as direct a manner possible through the house wall to the outside. To prevent air or gas returning into the house from the soil-pipe, and to completely disconnect it as far as possible, it is usual and necessary to bend the pipe, or even the terminal portion of the closet basin, into the form of an S, an arrangement which retains water and thereby prevents gas from passing back. The essential point about this artifice, commonly called a "trap," is that the bend be sufficiently great as to place some portion of the roof of the pipe below the water level, and the difference between the water level and the pipe-roof constitutes the *seal* of the trap; to be at all effectual, a water-seal in a trap should be not less than $1\frac{1}{2}$ inches deep. Though there are various other forms of traps, as will be seen later, practically the most useful form in connection with water-closets is the S or syphon trap. Now, like traps in other situations, those belonging to water-closets are liable to become unsealed by a great rush or volume of water passing into them, and emptying them of their safety water by what is known as syphon action. This is particularly liable to take place when two or more water-closets discharge into the same soil-pipe, with the result that the discharge from one sucks out water from the traps of the others. This accident can be best prevented by placing an anti-syphon vent in the crown or top of the trap, as shown in Fig. 48, and particularly in the case of a series of water-closets ranged one above another, and discharging into the same soil-pipe, by causing the ventilating pipe or vent from the trap of the lowest water-closet to join or receive, as it were, the ventilating pipe of each trap above, and the whole to be finally connected with the soil-pipe above the highest closet.

The various conduits or pipes within a house, and which run from either sinks or closets to the drain outside the house, are conveniently called "house-pipes." These house-pipes are made of either iron, lead, zinc, or of earthenware; those made of cast iron are the best, and should be so laid that an inspection of

them can be easily made. No pipe conveying house-refuse or sewage should be allowed to pass under a building unless no other means of construction is possible; in which case it must be laid in as direct and straight a line as can be obtained, and moreover be embedded in concrete 6 inches thick all round, laid at a depth below the surface at least equal to its own diameter, and finally ventilated at each end of the portion beneath the building. Some builders are extremely anxious to conceal pipes, particularly inside walls and under floors; such methods are not only bad, but very risky in case of leakage; in all cases it is infinitely better to run pipes at once by the nearest way through the wall to the outside of the house where it can join the proper drain.

The majority of houses now built for the upper and middle classes contain baths and bath-rooms. No bath-room should open out of bedrooms unless used exclusively by that bedroom's occupants. The best place for a bath-room is at the side of the house, so that its waste water can be readily carried away outside. The custom of placing a bath in a water-closet is bad, as it not only makes the water-closet useless to the rest of the household when the bath is occupied, but it further causes the bather to breathe foul air if any imperfection exist in the closet fittings. Like closets, bath-rooms need to be well ventilated, and their walls and floors covered with some impervious material; for these floors ordinary oil-cloth or linoleum is as good as anything.

Although the shape and material of which a sink is made are not of great moment, still the construction and destination of its waste pipe are of importance. Formerly the plan was simply to carry all sink-pipes directly into the soil-pipe. The consequence was that foul smells and gases often came up through them, rendering houses both offensive and unhealthy. It is now recognized that the only proper and safe plan is to take care that no pipes whatever join the drain except the soil-pipe of the water-closet. All other pipes carrying slop or waste water ought to deliver freely into the open air above a grating which covers the trap leading to the drain. All sink pipes need to be provided with a trap to collect the grease which forms so large a part of the refuse water sent down from scullery or kitchen sinks. The common bell-trap, so often met with in sinks, is really of little use except for partially preventing solid matter passing down and choking the pipe.

Slop Closets.—In some towns, particularly in Lancashire and Yorkshire where a sufficient water supply is not available, or precluded by financial reasons from being utilized for flushing and washing-out water-closets, advantage is taken of the household waste water to do this necessary cleansing. Closets from

which the contents are removed by the slops or refuse liquids of the household, instead of by clean water supplied for that purpose, are called slop-closets. Of these there are two kinds, namely, those in which the waste is allowed to run directly into the basin, or is poured down by hand; and those in which, with a view to give a better flush, the waste liquid is held up or collected in a suitable contrivance, and then discharged from time to time in a sudden forcible stream; these latter are distinguished by the name of "automatic slop-closets." Of the

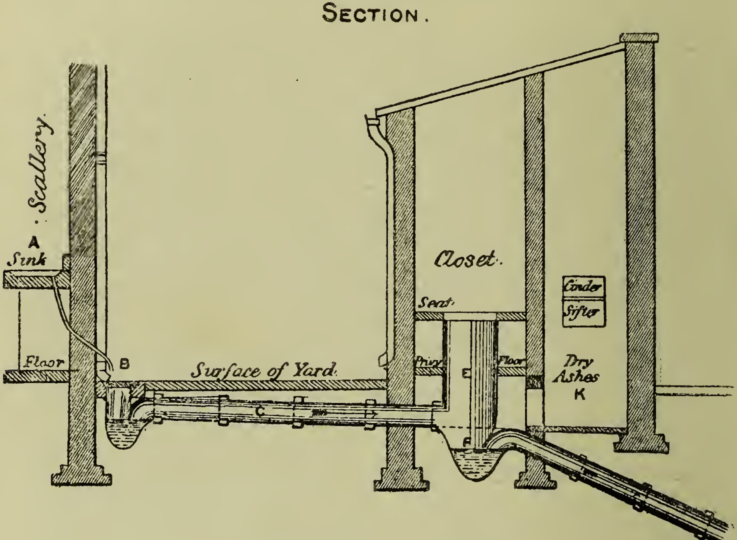


FIG. 49.—Fowler's slop-closet.

former variety, perhaps the best type is that known as Fowler's closet, largely in use in Newcastle, Salford, and Hanley. The general arrangement of these slop-closets will be readily gathered from Fig. 49. The objection to these closets is that the force or stream of water is often insufficient to keep them clean; also the closet basin is apt to get fouled at the back and sides by excrement falling against it, besides which improper substances are readily thrown down it and block the pipes. To get these closets to work well, a fall of at least 5 feet to the sewer is necessary.

Another form of slop-closet, is that of Hill, in use in Birmingham, in which either a syphon, cistern, or tipper is used to collect the slop-water, and then discharge it in a sudden flush. Fig. 50 shows this arrangement; experience indicates that the

tipper is preferable to the syphon tank, as the latter often will not act owing to clogging with greasy water. A number of closets can be placed on one drain, a single trap serving for the whole, this being placed at the bottom of a manhole for convenience of access; a ventilation-shaft is provided at the upper end.

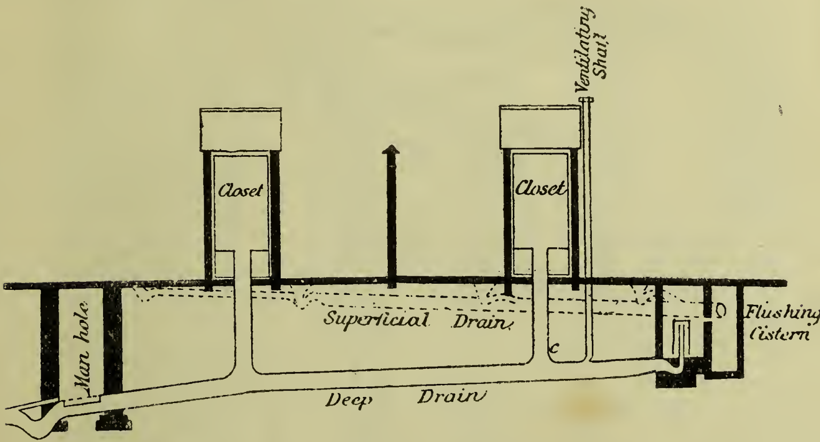


FIG. 50.—Hill's "automatic slop-closets."

An improvement and development of these closets are the various kinds of automatic slop-closet, in which the slow and uncertain trickle of the slop-water from the sinks is replaced by a sudden gush of the slop-water after storage in either a syphon, cistern, or a tipper. The tipper is merely a metal vessel, so shaped and balanced on pivots that when full the weight of the contained liquid overbalances it, and causes its contents to be suddenly poured down the pipe. As already stated, syphon-cisterns are unsuited for the storage of dirty or greasy water; so that practically the tipper is the best contrivance for this purpose. There are several varieties of these automatic slop-closets; in some the tipper is placed close to the sink discharge-pipe (top flushing), in others the tipper is placed well away from the slop-stone, and more or less in a piece with the lowest section of the closet-shaft (bottom flushing). The best forms of these closets appear to be Duckett's of Burnley (Fig. 51). The device as to these closets is mainly a question of suitability to any particular place. The tippers, to be effectual, must contain at least three gallons of water for single closets, and five gallons if flushing two or more closets in a row. Some kinds, such as Whalley's, do not have a self-acting tipper, but one discharged by pulling up a handle.

Others have the tipper situated at the side or back of the closet-basin (Fig. 52). The various automatic slop-closets appear to be advantageous in that their original cost is small, they consume less water, produce less sewage, and, too, are less apt to either freeze or get out of order than the ordinary water-closets; against them are the facts that they are unsightly, less cleanly than water-closets owing to fouling and lodgment of excreta on the sides. Their use can only be recommended out of doors, and when the sewers have a good fall and a public service of water is laid on to each house. It is also important that each house should have a separate closet. Subject to these conditions, these slop-closets may be of great use and value in towns and suburbs, especially when it is desirable to economize the water.

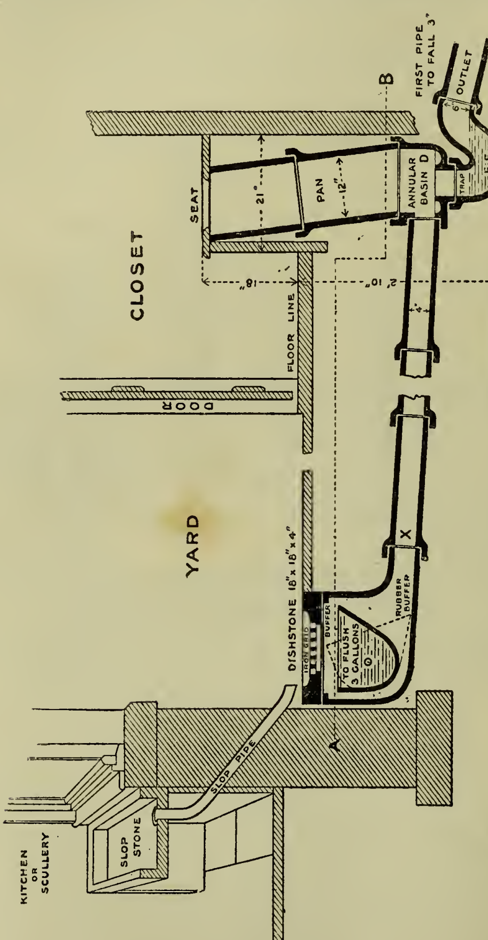


Fig. 51.—Duckett's "automatic slop-closet."

Trough Closets are those in which a long metal trough filled with water passes beneath the seats of a number of closets placed side by side, and receives the excreta from them. From time to time, these troughs are flushed out by the discharge of a volume of water either by an attendant, or automatically by a syphon-cistern or tilting receiver, and the contents carried away to the sewer

through a trap at the end of the trough. These closets are adapted for schools, factories and groups of artisan's houses, being little liable to get damaged by rough usage or get out of order: the only desideratum being a good large drain well-jointed with cement, and plenty of water. Their drawbacks are, original cost, the large quantity of water used, and the alarming noise and splashing which results if the flushing happens to take place when the seat is in use. Trough-closets, whether automatic or otherwise, can only be used where good drains exist and a supply of water is laid on.

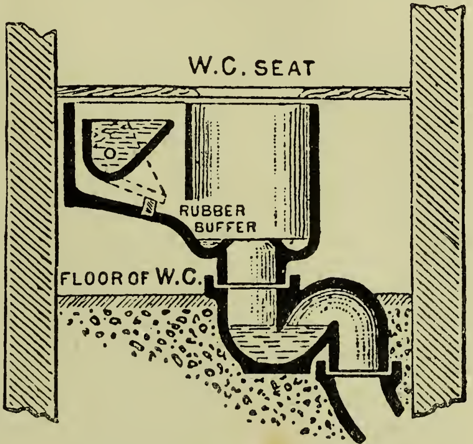


FIG. 52.—Duckett's Blackburn closet.

Middens.—In places where no facilities exist for the use of any of the various kinds of water-closets, recourse has to be had to some dry method of removing excreta from the house. This embraces such arrangements as middens, or privies and pail-closets, whether used with ashes, charcoal or earth. The institution of middens, or the setting aside of some spot for depositing filth and refuse, though a most objectionable and insanitary arrangement, was probably a great advance on the more primitive method of depositing everything anyhow and anywhere. Objectionable as they are, it is unfortunately a fact that middens or privies in some form or other exist still, not only in rural districts, but in certain towns, the essential principle in all being an attempt to both dry and deodorize excreta and refuse by an admixture with ashes. The original midden, if not a heap of decomposing filth, was at best but a hole dug in the ground more or less full of rotting matter, and giving rise to most offensive gases and liquids, which only too readily polluted both the soil around houses and the wells near them. In the present day, where middens do remain, their existence is subject to certain definite rules and conditions; these are briefly as follows. The midden or privy must be at least six feet away from any dwelling, and fifty feet away from any well, spring or stream; ready means of access must be provided for

the scavenger, so that the contents need not be carried through a dwelling; the privy must be roofed to keep out the rain, and be provided with ventilating apertures as near the top as possible; that part of the floor which is not under the seat must not be less than six inches above the level of the adjoining ground, and moreover be flagged or paved with hard tiles having an inclination towards the door of the privy of one-half inch to the foot, so that liquids spilt upon it may run down outside, and not find their way into the receptacle under the seat; the size or capacity of this receptacle may not exceed eight cubic feet, by which limitation a weekly removal of its contents is necessitated; the sides and floor of this receptacle must be of some impermeable material, the floor being at least three inches above the adjoining ground level; the seat of the privy should be hinged so as to allow of the ashes being readily thrown in, and the receptacle unconnected with any drain or sewer. Constructed and maintained under these conditions, it is probable that the risks of fouling either soils or wells are reduced considerably; while the pollution of the air is safeguarded to a large degree by the maintenance of the contents in a dry and inodorous condition. But depending as does the success of these middens upon sanitary supervision and scavenging, it is universally acknowledged that any form of them is unadvisable, no matter how well constructed and supervised.

The various forms of **Tub and Pail Closets** are really nothing more than miniature middens, in which the ash-pit is represented by a movable receptacle, such as tub or pail, placed under the seat for the reception of the excreta. It is claimed for these closets that the filth removal is much easier and the air pollution less than when midden contents are removed. The pails, whether of wood or of galvanized iron, should have close-fitting lids, and be both air and water-tight. The structure of the closet in which pails are used should be similar to that proposed for middens. The pail or tub should be removed not less often than once a week, and a clean one substituted for it. To avoid unhealthy smells it is most important that the contents of the pails (urine and fæces) should be kept as dry as possible. This can only be effected by adding to the contents some dry and absorbent material such as ashes, charcoal, earth, or even lining the pail with some absorbent substance such as sawdust or peat. If the mixed urine and fæces be left to themselves in the pails, they rapidly undergo decomposition, but in this state they have a higher commercial value as manure than if mixed with ashes, charcoal, or earth. Various modifications in this respect are in use in various towns; thus in Nottingham not only ashes, but all other household refuse is added to the pail, while in Leicester

and Birmingham the pails only receive excreta. The presence of the urine tends much to increase decomposition, but its separation is not only practically difficult, but an actual loss of fertilizing material if intended for manure. In Manchester only the fine ashes after sifting are allowed to fall into the pails; while in Halifax, what is called the Goux system is in use, the pail being lined with a layer of peat, or a mixture of tan, sawdust and soot, substances which render the contents drier and less offensive. Sifted house cinders and ashes form very efficient deodorizers and desiccators, and being always found on the premises of any house are more readily usable than either charcoal or earth. Both these latter substances are also used in pail-closets. In Stanford's closet the charcoal used is prepared from seaweed, about $\frac{1}{2}$ lb. being used each time. Neither ashes nor charcoal have the same beneficial and disintegrating action on the excreta that dry earth has. For this reason, earth-closets have had in one place and another a very extensive trial. About $1\frac{1}{2}$ lb. of clean dry earth is thrown upon the pail contents, either automatically from a hopper, or by hand every time the closet is used. The best kinds of earth for the purpose are loamy surface soil, vegetable mould, dry clay, or brick earth. Chalk, gravel, and sand are not suitable. Care has to be taken that the earth stored is sifted and dry, and that each particular stool is covered at once with the earth, and no slop-water added to the pail contents. Earth-closets are practically the only form of closet used throughout the whole of India, where, on the whole, they work extremely well. If a pail-closet is going to be used at all, from a sanitary point of view the earth-closet is the best form, as, if properly managed, the closet is free from smell and the process of removing the contents not offensive. In addition to this, the earth is readily obtainable, and not without value as an application to both fields and gardens.

As regards any question which might arise as to which kind of closet should be placed in any particular house or group of houses, the answer would depend entirely upon the circumstances of the case. Middens, being contrary to all sound principles of hygiene, should in no case be adopted when facilities exist for any other arrangement. For the better class of houses, water-closets or earth-closets are best suited in the country, and water-closets alone in towns. For houses occupied by the artisan class in towns, it is probable that slop water-closets are preferable to pail-closets. The experience of towns where these latter have been in long use goes to show that they are expensive to work, and that the ashes and other dry refuse are so difficult to dispose of as manure, that much of them has to be got rid of by burning

in destructor furnaces, a process which the presence of excrement renders more difficult. These are circumstances which render it desirable to separate, as far as possible, the excrement from the solid refuse of the town, and remove it rapidly by the increased facilities afforded by the now very general development and maintenance of public water supplies and sewers. For mills, factories and schools, trough-closets are undoubtedly the best.

In towns and places where either water-closets in some form or other, or pail-closets for excreta alone are in use, arrangements must be made for the removal of ashes and kitchen refuse separately. Inasmuch as these can only be removed at intervals from the houses where they accumulate, it is important that they be so stored as to remain free from offence while still on the premises. The articles most likely to become offensive are organic matters, particularly kitchen refuse. In all properly conducted households, these are invariably burnt in the kitchen fire, while only the indestructible matter is placed with the dust and ashes. This practice should be invariably carried out in all dwellings and families. Formerly, the receptacles for ashes and house refuse were dust-bins constructed of brickwork, leaning upon a yard-wall, or against the side of the house, with a wooden cover and a door at the side or front for the removal of contents. This faulty arrangement rendered the contents of the dust-bin extremely liable to become wet from rain, resulting in steady decomposition of the organic refuse with the production of much offensive gas and smell. So glaring were the defects of this system that it has become largely replaced by the provision to each house of small covered tubs or galvanized iron pails or boxes placed in an out-house or yard, and regularly emptied at short intervals. In some places, especially for large establishments, large water-tight bins or so-called dry ash-pits are used, the contents being removed at less frequent intervals.

The more detailed account of the ultimate disposal of the contents of water-closets, pail-closets, and dust-bins is given in the succeeding chapter.

Schools.—It is a remarkable fact that, up to within the last few years, the hygiene of schools and school-houses has received but a small amount of attention. The general principles laid down in the preceding pages as to site, surroundings, construction and drainage of ordinary dwelling-houses, apply equally to schools. Schools may roughly be divided into three great groups: (1) those under State or public control, such as Board Schools and those in Poor-law institutions; (2) the large residential schools and colleges for the upper, middle and lower classes throughout the country, usually under the control of nominated or elected

governors; (3) private schools or colleges, more or less conducted by irresponsible teachers or proprietors. In regard to the schools included within the first two groups, considerable supervision is exercised with reference to questions concerning the health of the scholars as a result of the actions of officials of the Education Department of the Privy Council, the School Boards, the Local Government Board, and the Association of Medical Officers of Schools. But, in the case of the purely private schools, there practically exists no controlling authority as to their arrangements and construction. The chief hygienic defect in the arrangement of all schools appears to consist in the undue aggregation of the children. Oddly enough, this is notably so in those schools which come under the inspection of the State, or in respect of which there is a grant of money calculated upon the number of children and the degree of education attained. This tendency to overcrowding in schools lowers the general health standard of the scholars, fosters any liability to disease that may exist in the individual children, and, at the same time, promotes the spread of any communicable or infectious complaint that may be introduced among them.

The Education Department of the Privy Council requires all schoolrooms to have a width from 18 to 22 feet, and states that if the width does not exceed 20 feet, groups of three long desks must be used, but if the width is 22 feet, then dual desks, five rows deep, must be used. Each child or scholar must be allotted 18 inches on the long desks, with gangways 18 inches wide between the groups. When the dual desks are used, and which are 40 inches long, then the gangways between them need only be 16 inches. The height of the rooms must be from 12 to 14 feet; these dimensions give an average floor area of 10 square feet, and a cubic space of about 125 feet to each child. In infant schools, the floor area demanded is only 8 square feet per child, which, with rooms of the foregoing measurements, gives scarcely 100 cubic feet per head. These standards are very low, and only justifiable if the warming and ventilation arrangements are so complete that the air of the rooms will be constantly changed without draught or unduly affecting the room temperature. Unfortunately this is not so; the only mitigation lies in the fact that where the schoolroom is of the required size for the whole number of children attending, or supposed to be attending, the absences of certain numbers gives the remaining children the benefit of additional space. The theoretical requirements for a child in an elementary schoolroom is 400 cubic feet, and for a lad in a large public school, 800 cubic feet as minima; it is, however, doubtful whether such amounts can ever be obtained. Few

large schoolrooms can be adequately ventilated except by artificial means; while their warming is best done by steam or hot-water pipes from some central apparatus in the basement. The smaller rooms can be efficiently heated by means of open or closed stoves, particularly if utilized to aid ventilation by warming the incoming air, as, for example, in Galton's grate.

The lighting of schoolrooms is of the very greatest importance. The window area should not be less than one-tenth of the floor area, and may, with advantage, be made quite one-sixth. Every window should be carried up to the ceiling and be made to open. They should be so arranged that the light is admitted as much as possible on the left side of the pupils; strong light from behind, or from directly in front, should be avoided. The seats for the scholars should be at least 9 inches wide, and about the height of the knee; it should also be provided with a back. The desk ought to slope, its edge reaching a little over the front edge of the seat, and be at the height of the scholar's elbow.

In addition to the school- and class-rooms, all residential schools must have other rooms for either taking meals in, for recreation in wet weather, and for affording sleeping accommodation. Such rooms should at least afford as much space as has been mentioned for ordinary schoolrooms, if not more. In the case of dining-rooms or halls, care should be taken that, as regards its means of ingress and egress and relation to the domestic offices, it should be so arranged that the food is capable of being served to the children both hot and in a palatable condition. As to dormitories, the usual width in the Poor-law schools is 18 feet, each bed having a minimum of 3 feet 9 inches of wall space, 36 square feet of floor area, and 360 cubic feet of space. If the room is only 15 feet wide, the wall space is increased to 4 feet. There is reason to believe that very few private schools, even those of the best class, afford more than 300 cubic feet of space per head in their dormitories, an allowance which is quite inadequate. Dr. Dukes, of Rugby, advocates for our climate 800 cubic feet of space, with some 70 square feet of floor area for each child in all school dormitories. In all schools, the permitting of children or scholars to sleep two in a bed should be most rigidly opposed.

In all school lavatories or wash-houses, supervision needs to be exercised to see that all children wash daily, and that no two of them use the same water. Each child should have a separate towel, and the use of round roller-towels forbidden. The regulations of the Local Government Board lay down that bathing arrangements in the Poor-law schools must admit of every child being bathed at least once a week in winter, and twice a week in

summer; and certainly in other schools, no matter whether public or private, the bathing facilities ought not to be less.

The next important point in connection with schools is their closet accommodation. For day use, outdoor closets should be provided, and so placed that they are not unduly remote; they should also be well lighted, in case of being required after dark. The closets for girls must be quite separate from those used by boys. The actual number available ought to be at least 15 per cent. for girls, and 10 per cent. for boys, *plus* 5 per cent. of urinals for the latter. Each dormitory in a school should have an accessible closet. The precise kind of closet best adapted for schools is the trough, or flush, closet. Several schools have tried the dry system, but with only partial success.

Hospitals.—All that has been said in respect of site, surroundings and construction of houses and schools applies with still greater force to hospitals. As charitable institutions, existing for the purpose of affording medical and surgical aid to the sick poor, hospitals, on economical grounds, have largely to be so constructed that the patients may be grouped together in general wards. It is this aggregating of large numbers of sick or diseased persons under one building that constitutes the most important factor in hospital hygiene. It has long been known that overcrowding in the wards of hospitals is productive of the worst results, particularly in surgical wards, where the neglect of proper sanitary measures produces the class of diseases known as "septic," of which well-known forms are erysipelas and blood-poisoning. Bearing this fact in mind, we are able to understand that the chief conditions to be avoided in all hospitals are: (1) insufficiency of cubic space; (2) inefficient ventilation; (3) improper arrangements for the removal of excreta, refuse, soiled linen, dressings, poultices, etc; (4) faulty arrangements of the buildings.

Insufficiency of cubic space and inefficiency of ventilation go together; in fact, mere cubic space of itself is of little value, unless accompanied by adequate ventilation. As a general rule, it may be said that large wards are more readily ventilated, warmed and managed than small ones. The most general form of hospital wards is rectangular; but in a few hospitals they are circular; and in the John Hopkins Hospital, Baltimore, there are octagonal wards. The dimensions of wards are dependent upon the number of patients to be accommodated and the amount of cubic space to be allotted to each. Rectangular wards vary from 24 to 30 feet in width, 13 to 14 feet in height, and from 30 to over 100 feet in length. The late Drs. Parkes and de Chaumont considered that each patient should have from 100 to 120 square feet of floor area, and from 1500 to 2000 cubic feet of air space.

For fever, severe surgical or lying-in cases, the requirements are greater, being about 3000 cubic feet of air space and 140 square feet of floor area. Experience shows that nursing is best carried out when the number of beds in a ward do not exceed thirty or thirty-two. These beds are best arranged with their heads to the wall and facing into the ward. Each bed should be placed between two windows, or, at most, two beds in between two windows. The windows ought to be opposite one another, and should extend from 3 feet above the floor to within 6 inches of the ceiling; they should all be capable of being opened at their upper parts. One square foot of window may be provided for every 80 cubic feet of space in the ward. The heating of hospital wards may be effected by open fireplaces or ventilating stoves, or both, or by hot-water pipes. The temperature of wards is best kept at 60° F. To secure adequate ventilation, the air is best warmed before passing into the wards. This may be done either by means of ventilating stoves, Galton's grates, or by coils of hot pipes at inlets placed beneath the heads of the beds. Extraction of foul air is provided by fireplaces, stoves, windows open at the top, or by special shafts. In some infectious hospitals, such extraction-shafts are made to lead to a furnace, the heat of which serves both as a means of extraction and a means of destroying any germs which may be in the outgoing air. It is needless, perhaps, to say that the floors should be impervious, free from crevices and polished; the walls ought to be lined with tiles, cement or glazed brick; or, failing these materials, simply painted. The junction of floor and the walls may be made round, so that dust can be easily seen and removed.

Circular wards for hospitals were first advocated in this country by the late Professor Marshall, in 1878; the advantages claimed for them being: (1) freedom of frontage to all points of the compass, and, consequently, greater accessibility to both light and air; (2) greater area contained within a given length of wall; (3) greater facilities for administration and cleanliness. For many years this idea of circular wards received much opposition, more particularly from architects, on the plea that they would be very expensive to build. Circular wards now exist in various hospitals, both in this country and on the Continent, notably at Antwerp, Greenwich, Burnley, Liverpool, Hastings, and Milton near Gravesend.

The need for speedy removal of all excreta and refuse is of paramount importance in hospitals, as in private buildings; the principles to be adopted are the same as have already been explained.

As regards the faulty arrangement of hospital buildings, the

chief defect usually met with is the absence of effective separation of the wards from the other parts, with due regard to economy of construction. The precise disposition of the several parts of a hospital in relation to each other, of necessity greatly depends on the size of the hospital and on the shape and area of the site; but the really essential principles which should guide us in constructing a hospital are, briefly: (1) an avoidance of all intimate connection between the wards and the administration buildings; (2) separation of medical from surgical wards; (3) complete atmospheric disconnection between the wards on the one hand, and the mortuary, laundry and out-patient department on the other (Keith Young).

To secure these results, the most common plan now is to build hospitals upon what is called the pavilion system. This system is merely the arranging, on a plot of ground, of a series of one, two or more story buildings, called pavilions, and connecting them together by corridors or covered ways. The individual pavilions or blocks of buildings may be of any shape or size, as, for instance, in the new Great Northern Central Hospital, London, where, although there are both circular and oblong wards, they are all practically isolated from each other and from the rest of the hospital. Care should be taken to see that the various buildings are not so close to each other as to seriously interfere with the free circulation of air, or shut out light. A good rule to adopt is, if of two buildings one is higher than the other, the distance between them must be equal to the height of the higher; if two buildings are of the same height, then the distance must be one-and-a-half times the height.

Besides ordinary or General Hospitals, there are a number of what may be called Special Hospitals. Among these latter are such hospitals as those for diseases of the eye, ear or throat; those for consumption, for children, for convalescents, for cancer or incurables, for lying-in women, and finally, those for infectious diseases. Although in all matters of structural hygiene these hospitals require the same care as the ordinary hospitals, still, in addition, they present some special needs. Thus, ophthalmic hospitals need the removal of sharp angles in wards against which blind or partially blind persons may accidentally injure themselves, and the provision of handrails on both sides of staircases. Open fireplaces are a mistake in these hospitals, as often the flickering flame of a fire is both trying and injurious to diseased eyes. Consumption hospitals require special warming and ventilation arrangements for their inmates, as well as liberal provision for those able to get up and move about. The most prominent need in all children's hospitals is an isolation ward, as young

children are extremely susceptible to infectious diseases. Convalescent hospitals are more properly homes for those recovering from acute illness, rather than mere hospitals for the sick. In the same way, cancer and incurable hospitals need to conform more to the freedom and independence of home life than to the more rigid arrangements of the institutions for treating acute cases. Lying-in hospitals, from the peculiar nature of the cases they receive, should be constructed with small rooms and not with large wards. Every such hospital should be provided with an isolation ward, absolutely distinct from the rest of the building.

Isolation, or infectious hospitals, are quite a class by themselves; they may be either permanent or temporary buildings. Reference has already been made to the need, in these hospitals, of greater cubic space and ventilation. Owing to the remarkable tendency to aerial spread of infection in the diseases taken to infectious hospitals, the communication with the outside world has here to be kept under the strictest control and each disease isolated separately, and kept if possible in separate blocks or buildings, the communication between which should be absolutely forbidden. Each block, besides wards, closets, bathrooms and sinks, should have linen, store and fuel rooms, as well as a nurse's room. The disinfecting chamber, mortuary and stables for ambulances and horses, should also be clearly disconnected from all other parts of the building.

Considerable controversy has taken place whether infectious or isolation hospitals should be permanent buildings or merely temporary ones. The truth probably lies in the view that all administrative arrangements, and a certain limited accommodation for the infectious sick, should be in permanent buildings, which existing thus ready to hand in non-epidemic times can be quickly supplemented by additional wards in either huts or tents within a few days, in case of wide-spread epidemics. Some means of isolation are needed in every community at all times, and it is a sounder policy to be able to delay and prevent epidemic outbreaks by isolating the few sporadic cases as they occur, in a small but permanent infectious-disease hospital, than have to grapple with epidemics already in full existence by means of hastily constructed, expensive and often costly temporary structures. Many materials have been suggested for the construction of these temporary buildings, more particularly wood, galvanized iron, canvas and waterproof paper. Although they are comparatively cheap and rapidly erected, temporary hospitals should never be regarded as able to supersede permanent buildings of brick or stone; their true use is to supplement, not to supersede. Moreover, they are extremely difficult to ventilate and to warm in winter or cool in

summer. Their durability is small, and their proper disinfection is almost impossible. Of course they can be burnt when done with; but if epidemics of infectious disease rapidly succeed each other, the renewals of temporary hospital buildings will soon exceed the cost of structures of a more permanent nature. As infectious hospitals, unlike the great bulk of general and special hospitals, are in no sense charitable institutions, but really public buildings provided and supported by rates, the true bearing and merits of the question whether these hospitals should be temporary or permanent buildings is one which intimately concerns the interests of every citizen.

CHAPTER V.

THE REMOVAL AND DISPOSAL OF REFUSE AND EXCRETA.

In order to secure proper sanitation, it is essential that all refuse should be removed as speedily as possible from the neighbourhood of dwellings. In thinly populated districts, sewage matters are returned at once to the soil, where the products of decomposition and decay are quickly dealt with without becoming a source of danger; deodorization and oxidation are effected, and the fertility of the soil largely increased.

When, however, men collect in communities, the difficulty arises of how to get rid of excrementitious matters and waste products without their becoming a danger to health. These refuse matters consist of fæces, urine, house refuse collected from ash-pits and dust-bins, waste waters from houses and factories, refuse from stables and from various trades, dust, road-sweepings, etc.

On an average, 4 ozs. by weight of solid and 50 ozs. by measure of liquid excreta are passed daily by an adult person. Vegetable feeders, as a rule, pass more owing to the larger proportion of water in their food. In a mixed population, the daily average amount may be taken at $2\frac{1}{2}$ ozs. of solid and 40 ozs. of liquid excreta. In a year, therefore, 1000 persons pass 25 tons of fæces, and 91,250 gallons of urine.

Fæces are acid when first passed, and remain so for a considerable time, if unmixed with urine and dry; when fæces and urine are mixed together, decomposition with the formation of ammonium carbonate rapidly takes place, and fœtid organic matters are given off. When the solid excreta, free from urine,

decompose, fœtid organic substances are disengaged, but sulphuretted hydrogen is seldom detected. In the urine, urea is rapidly decomposed into carbonic acid and carbonate of ammonia. The following table gives the average composition of excrementitious matter passed by a male adult daily :—

	Fresh Excrements, ounces.	Dry Substances, ounces.	Mineral Matters, ounces.
Fæces	4·17	1·041	0·116
Urine	46·01	1·735	0·527
Total . . .	50·18	2·776	0·643

The waste waters from houses, factories and the rainfall and water used in cleansing and watering streets, are, as regards their composition, almost as foul as ordinary sewage.

The methods for the removal of sewage may be conveniently divided into the *dry* method, and the *wet* method; but many modifications of these two principal plans are in use.

Before entering on a description of these plans, it will be convenient to make some general observations on sewers and sewerage.

Sewers are conduits to carry away waste waters, waste products (including excreta) from factories and houses, and rain. Sometimes separate channels are provided to carry off the rainfall; this is called the "separate system," and it is based on the principle of "sending the rain to the river, the sewage to the soil."

In some cases, the sewer water, as measured at the outlet, is greater in amount than the water supplied to the town and rainfall together, and in this case the subsoil water gains access to the sewers.

The question whether the solid excreta ought to be passed into sewers has been the subject of much controversy; in all cases urine has been found to enter, and the inclusion or exclusion of solid matters makes little difference, as the amount of solids in one ton of average London sewage is only 2 to 3 lbs. of solid matter.

Sewer water varies very much in composition, being sometimes very turbid and highly impure; in other cases hardly more impure than water from surface wells. The Rivers Pollution Commissioners give the average composition of sewage to be :— combined nitrogen 7·728, ammonia 6·703, and chlorine 10·66 parts per 100,000. In London the quantity of sewage during the

dry weather amounts to 36 gallons per head daily or 60 tons per head per annum; this is increased by rainfall and subsoil water by from two-thirds to an equal volume. In pipe sewers the amount of sewage is equal to the water supply, about 20 gallons daily or 33 tons per head per annum. Sewers are, therefore, necessary in every populous place to carry away waste waters, if for no other reason; formerly they were emptied into rivers and streams as being the readiest way of disposing of their contents, but this pollution is now forbidden by the Rivers Pollution Act, which has recently been amended so as to increase the powers of local authorities to prohibit this practice.

There can be no doubt about the main principle of sewage disposal, that animal waste products should be as quickly as possible submitted to the action of growing plants, and thus converted from dangerous impurities into wholesome food. The difficulty lies in its application.

According to one plan, the sewer-water is at once brought to the ground, and after arresting substances that may block pipes, it is poured over the land.

According to the other opinion this plan is bad because the substances are not brought to the ground in the most convenient form for agriculture, and because the immense quantity of water is hurtful. Therefore, the impurities are first separated and either applied to the land in a solid form, or used for some other purpose —as cement making—and then the purified water is either filtered through land, or passed direct into streams.

Removal of Excreta by Water.—The advantages of this method are that it is the cleanest, readiest and in many cases the cheapest method; the water used for domestic purposes is utilized to carry away the excreta. The success of this plan depends on there being a good supply of water, properly constructed sewers, with good ventilation and proper outfall and means of disposal of the sewer-water. The quantity of water necessary to flush sewers and maintain them in a healthy state is 25 gallons per head per day. If rain-water passes in, it flushes the sewers thoroughly sometimes, but it also carries in gravel and debris and may burst the sewers in certain cases, to provide against which storm-overflows should be provided.

House-pipes and Drains.—House-pipes are the channels or conduits inside the house, and these are either *soil-pipes* connected with water-closets, or *sink-pipes* for carrying away waste water. House-pipes lead into *drain-pipes*. Engineers are now desirous of restricting the term "drain" to a pipe that merely draws off moisture from land, using the term "sewer" for a pipe carrying sewage or liquid refuse of any kind; but by the

Public Health Act, 1875, sec. 4, a "drain" means the drain of one building or premises in one occupation leading into a sewer or cesspool; and "sewer" means the channel receiving the "drains" of two or more premises.

Pipes outside the house are usually made of iron and are best if glazed on the inside; iron pipes not so protected should be tarred in their interior and the joints made water-tight by means of lead. In the "Durham" system of house drainage the pipes are of wrought iron, lined with cement, and jointed together by wrought-iron collars and cast-iron bends and junctions; it is said by this system faulty jointing is an impossibility. Pipes usually are 4 inches in diameter, and those leading from any water-closet in the upper part of the house should be outside the wall of the house; while the pipe from the water-closet should be obliquely connected with the soil-pipe and have air-tight joints.

To secure ventilation the soil-pipe should be carried full bore upwards above the roof, without angles or bends, opening away from any windows and not connected with chimneys; all junctions should be capable of inspection.

At the junction of the house-pipe with the drain there should be complete disconnection, not only by means of a good water-trap, but also by connection with the external air at the point of junction, so that the union with the drain may be broken both by water and ventilation. Buchan's disconnecting and ventilating drain-trap, or the form of manhole designed by Mr. Rogers Field, secures this action.

Waste pipes discharging waste water from kitchens, lavatories, baths, cisterns, etc., should not connect directly with any drain, but must discharge into the open air over a grating covering a good water-trap; they should not be made to open under the grating, as sewer-gas may be sucked up through the pipes by the higher temperature in the house. Waste pipes should also be furnished with disconnecting syphons in addition to opening over gully-traps in the external air.

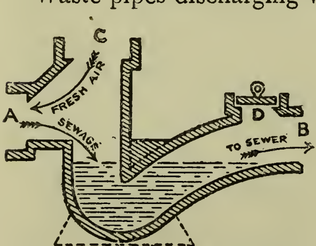


Fig. 53.—Buchan's disconnecting and ventilating Drain Trap.

A good form of disconnecting trap for sinks and slop waters is Dean's (Fig. 58), which has a movable bucket for removing deposits.

Traps are frequently the only safeguard against sewer-air entering a house. They are almost of infinite variety, but may be conveniently divided into the *syphon*, the *mid-feather*, the *flap-trap*, and the *ball-trap*.

The *syphon* trap consists of a curved tube, the curve being full of water which should stand at least three-quarters of an inch

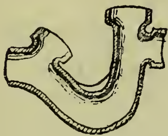


FIG. 54.—Syphon Bend.

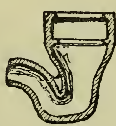


FIG. 55.—Syphon Trap.

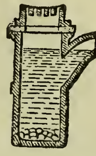


FIG. 56.—Gully Trap.

above the top of the curve. If two syphon-traps succeed each other, one will suck the other dry, unless an air opening is placed between them; the syphon is the best variety of trap.

The *mid-feather* consists of a round or square box, with an

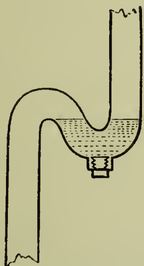


FIG. 57.—Syphon Sink Trap with movable screw for cleaning.

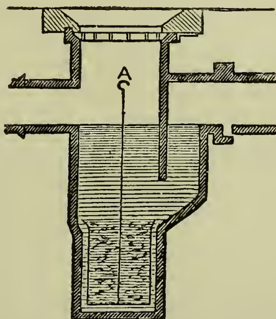


FIG. 58.—Dean's Gully Trap. A, Handle of movable bucket.

entry tube on one side and an exit tube at the same height on the other; water stands in the trap up to the lower margin of each pipe, and a partition passes down between into the water (Fig. 59). It is not a good form of trap, as it is not self-cleansing;

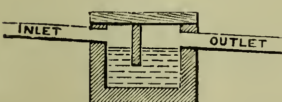


FIG. 59.—Mid-feather Trap.

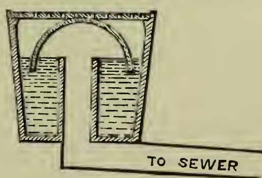


FIG. 60.—Bell Trap.

it is also liable to leak under the covering-stone, when the gas readily escapes.

The *bell-trap* is a modification of the mid-feather principle: it is a very inefficient form of trap (Fig. 60).

The *flap-trap* is a hinged valve allowing water to pass in one direction: it was expected that this would prevent the reflex of sewer-air, but it has been found to act very imperfectly, and is useless to prevent gas returning.

The *ball-trap* is one in which a ball rises with the rise of water and closes an orifice: it is a very imperfect form of trap.

Concerning traps generally, engineers look suspiciously on every one of them, and endeavour to render them unnecessary by thorough ventilation and disconnection of the drains.

The essentials of a good trap are that the water stand at least three-quarters of an inch above any openings, and that the trap itself is self-cleansing. A trap is only efficient so long as it contains water: if not in constant use, especially in dry weather, the water evaporates and direct communication is established with the drain. In dry weather frequent flushing is therefore necessary.

To prevent the deposit of grease or sand in the drain-pipe, a grease-intercepting chamber is sometimes necessary. This chamber is generally made of hollow stoneware, with a tight iron cover, and ventilated. The hot water from the sink is cooled on entering the chamber, the grease solidifies and rises to the top, the sand sinking to the bottom: the grease and sand must be removed periodically. Rain-water pipes as well as waste pipes from sinks, baths, etc., should end below over a gully-trap so as to be completely cut off from the drain.

Gully-traps should be at least eighteen inches from the wall of the house, and their superficial surface should be as small as possible, so as to diminish the evaporation of water.

Syphon-traps, however perfectly made, cannot be relied on to prevent the passage of sewer-air. Water alone cannot always resist the pressure of air, and even if it accomplishes this it will absorb foul gas from below and emit it above; hence the absolute necessity for disconnection and the ventilation of the sewers.

Drain Pipes are commonly made of glazed stoneware 4 inches to 9 inches in diameter, usually they are 4 inches to 6 inches; if larger the flow through them is too slow; they should be very carefully laid on concrete; if the foundation is not good, leakage will occur. The joints of stone pipes should be water-tight; the "Stanford" form of joint is well spoken of, and has the advantage of being readily and easily made. The composition used in Stanford's joint is composed of one part of boiled tar, one part of clean sharp sand, and one part and a half of sulphur. Some builders are now using iron pipes in lieu of stoneware. They have the advantage of fewer joints, but should be well coated with Angus Smith's or some similar solution to prevent rust; the joints should be run with lead and not made with cement.

All junctions with the drain-pipe should be oblique and not rectangular: the use of the latter usually results in stoppage of

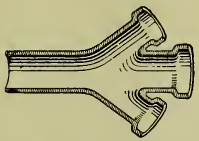


FIG. 61.—Junction Pipe.

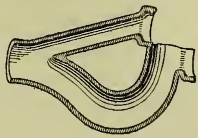


FIG. 62.—Trap with Inspection Pipe.

the pipe. The junction of drains is made by a special form of pipes, which may be either single or double junction.

It is also advisable at every change of direction that there should be means of access to allow of the drain being examined.

The drain-pipe should not, if possible, run beneath the house; but, if this cannot be avoided, it is best to have it exposed to view by taking it above the basement floor, or otherwise it must be embedded in and covered by concrete, not less than 6 inches thick all round.

The inclination or fall required for drains is 1 in 40 for 4-inch and 1 in 60 for 6-inch pipes; too much dip will cause the water to run away too forcibly, leaving the solid matter behind; if the fall is less, or if deposits occur, special means of cleansing are required; this is usually accomplished by manholes placed at intervals, the drains running in straight lines from manhole to manhole. Builders, when constructing drains, usually lay down a half pipe where required; raise up the sides in brick lined with cement, and cover the space over with an air-tight iron cover.

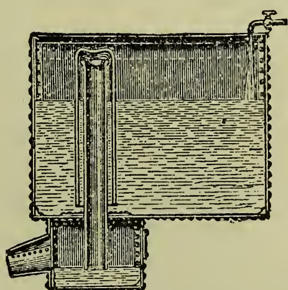


FIG. 63.—Field's Flush Tank.

When the current is feeble and deposits are liable to occur, automatic flushing tanks may be placed at the upper end of the drain. Field's automatic flush tank may be used for this purpose; it acts by syphonage, so that the whole cistern empties itself with a sudden flush when the action is started.

To examine Drains.—Pour water down the pipe and notice whether there is any smell, indicating want of ventilation in the pipe. The simplest method, perhaps, is to pour down the pipe, at the highest part, one ounce of oil of peppermint with a few gallons of hot water; as this is a very volatile oil, there is no difficulty in tracing whence the odour is emitted, and so detecting the leak. This is probably all that can be done inside the house, but the pipe may be inspected from the outside, and, if necessary,

the drain opened; lime water should then be poured down the soil-pipe from above, and the quick or slow appearance of it outside noted; if slow, the pipe requires flushing; if much discoloured, it indicates a foul state of the drain. It may be desirable to test whether the drain is water-tight. If the lower end of the drain is plugged, and the pipe then filled with water, any leak will be found by the sinking of the water in the upper part. Or the drain may be filled with smoke by a forcing apparatus, when the situation of any leak will be detected by the presence of the smoke—smoke rockets also may be used for this purpose. The smoke test, although convenient for testing traps and fittings above ground, is of no value in testing underground pipes. A drain may be leaking at every point, and yet appear perfectly sound on the application of the smoke test.

Sewers.—The outside house-drain ends in a channel of larger size common to several drains, constructed either of impervious brick or of stoneware piping. Cement pipes are better than earthenware; they are more durable and withstand frost and vibration of traffic better.

Two objects have to be aimed at: first, sewage has to be removed, and this should be done by impervious pipes, such as of glazed stoneware or cement, very carefully laid and jointed; and secondly, the subsoil must be drained, and this requires pervious drains, as of brickwork. Mr. Brooks of Huddersfield combined a sewer-drain and subsoil pipe, in which there is an arrangement for subsoil drainage under a pipe-drain (Fig. 64).

Main sewers of large size are always made egg-shaped, with the

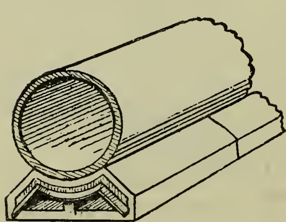


FIG. 64.—Brooks' combined Sewer-drain and Subsoil Pipe.

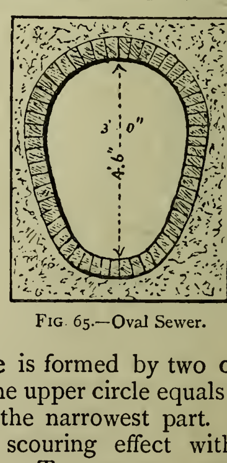


FIG. 65.—Oval Sewer.

small end downwards. The egg shape is formed by two circles touching one another; the diameter of the upper circle equals twice that of the lower, so that the invert is the narrowest part. This form of sewer secures the maximum scouring effect with the minimum quantity of water (Fig. 65). To secure a uniform

flow, it is necessary to diminish friction as much as possible; and this is found to be least in this form of sewer, as the wetted perimeter is proportionately reduced, instead of being, as in every other form of sewer, relatively increased. The interior should be smoothly finished and be quite impervious, and free from any inequality.

The size of sewers varies, according as they are intended for sewage only, or for rain-water as well. The first system, known as *the separate system*, is used for small towns, as being less costly than the *combined* system.

To avoid deposition of sediment, sewers should be laid in as straight lines as possible and with a regular fall; junctions should be made oblique, and if the sewer curves, it should describe a wide sweep, the radius of the curve not being less than ten times the cross sectional diameter of the sewer.

The fall varies according to size, usually 1 in 224 for a 15-inch sewer, and 1 in 784 for a 48-inch sewer. The velocity of flow should not be less than $2\frac{1}{2}$ feet per second, and 3 feet per second is better; but it should not exceed $4\frac{1}{2}$ feet per second, as the friction caused by the current carrying solid matters and gravel along would be liable to damage the interior of the sewer.

The calculation of the discharge from sewers may be made by using the following formula:—

$$V = 55 \times (\sqrt{D \times 2F})$$

Where V = velocity in feet per minute. D = hydraulic mean depth in feet. F = fall in feet per mile.

Then if A = section area of current of fluid, VA = discharge in cubic feet per minute.

To use this formula, the hydraulic mean depth when the sewage is flowing, and the amount of fall in feet per mile, must be first ascertained. The "hydraulic mean depth" is the section area of current of fluid divided by the wetted perimeter. In circular pipes it is always one-fourth the diameter. The "wetted perimeter" is that part of the circumference of the pipe wetted by the fluid.

An example may illustrate this. A circular sewer, having a diameter of 24 inches, is laid with a fall of 16 feet per mile. Calculate the velocity of flow and the amount of discharge, the pipe running full. Here the hydraulic mean depth is 6 inches, or 0·5 of a foot—we have $55 \times \sqrt{0{\cdot}5 \times 32} = 220$ feet per minute velocity; then the sectional area of the pipe running full = 0·7854 of a square foot $0{\cdot}7854 \times 220 = 172{\cdot}788$ cubic feet discharged per minute, and $172{\cdot}788 \times 6{\cdot}23$ (cubic feet in a gallon) $\times 60 = 64{,}588$ gallons per hour.

Ventilation of Sewers.—Sewers cannot be air-tight on account of the very numerous openings into them; the tension of the air

is not generally very different from that of the atmosphere outside, while the movement of the air is generally in the direction of the flow of current. Houses being warm act as aspirators to sewer-air, while the blowing off of steam increases the temperature and pressure suddenly, and may force sewer-gas through the traps. Tidal water in sewers is not so liable to do so, as the rise of the tide is gradual.

The ventilation of sewers is effected by means of open grids, placed at the street level at short distances—one in every 100 yards. Some will be inlets and some outlets, according to varying circumstances, air movement being always irregular and depending on the differences in temperature.

When sewer-gas can be detected from ventilators, deposits from the sewer should be removed and better ventilation provided. Factory chimneys may be used as uptake shafts, but these only influence a short section of the sewer. A sewer which stinks at its open gratings is giving evidence of its unsuccess, and for this reason it has been recommended that street gullies should never be trapped. Merely to trap street gullies, in any such case, would be greatly to increase the danger to houses; the remedy lies in providing better ventilation, and preventing deposit by intrinsic flushing at due intervals.

Manholes must be provided for the inspection of sewers; they should be fitted with iron steps for the sewer-men, and with a groove for a sluice, if required.

When the outfall is into the sea or a tidal river, it should either be below low-water mark or provided with a flap-valve, to prevent sewer-gas being driven back by the wind.

Points in the Construction of Sewers.—At each principal change of line or gradient there should be arrangements for inspecting flushing and ventilation; at all junctions and curves the fall should be increased to compensate for friction; the principal sewers should have special overflow pipes for excess of rain; no junctions should be at right angles, nor opposite other junctions; tributary sewers should deliver in the direction of the main flow, and should have a fall into the main at least equal to the difference between their two diameters; pipes of small size should always join on to pipes of larger size; if the tributary joins the main sewer below the level of the sewage in the latter, deposits are produced in the branch. Street gullies are generally provided to prevent the entry of gravel and solid matters into sewers. The debris collects in the gullies, while the water flows off by an opening to the sewer placed on a higher level, and the deposit removed at intervals.

Disposal of Sewer-water and Sewage.—The difficulty of removing excreta by water really commences at the outfall, when

the sewer-water has to be disposed of; and the admission or exclusion of the excreta makes little difference in the problem of the disposal of foul water from houses and factories.

The plan formerly adopted for the storage of sewage in a tank has now been almost altogether abandoned. The sewer-water ran into a cemented tank, with an overflow pipe; the solids, after subsiding, were removed from time to time, while the liquid was allowed to run away into the subsoil.

The cesspool or dead-well is similar to this; it is really the only method available in a country place. In this system the tank can never be quite water-tight, therefore the surrounding soil gets polluted and the water-supply must not be derived from anywhere near; the amount of percolation depends largely on the nature of the soil. At Northampton the spongy sandstone is so absorbent that it is a principle with Northampton builders that a cesspool needs no drain (Corfield). The nature of the soil has also a great effect on the purification of sewage, depending on the presence in it, and if so in what quantity, of the nitrifying ferment. Complete disconnection by proper traps and efficient ventilation are necessary to make this a sanitary method.

When sewers discharge into the sea, the outlet should always be under water; there should be a tide flap opening outwards, to prevent ingress of tide and wind blowing up; the tide will block sewage at certain times, and this, in the case of low-lying towns, necessitates a "tank sewer," to store the sewage that flows down during this period; but with this method, decomposition and evolution of gas and ammonia compounds are very liable to take place; it requires special attention.

Purification of Sewage.—This presents great difficulties, and the problem has yet to be solved. The methods employed are:—

1. Chemical treatment.
2. Intermittent downward filtration.
3. Irrigation.

One of the principal substances used for precipitating, is milk of lime. The quantity used varies from 6 to 12 grs. of quick-lime for each gallon of sewage. If the effluent is made alkaline by the addition of too much lime it undergoes putrefaction rapidly; it has been attempted to prevent this by adding chloride of iron to the quicklime, by which means putrefaction is delayed but not prevented; the process is simple and cheap, but as the organic matters in suspension only are acted on, it has failed to produce either a valuable manure or the purification of the offensive liquid.

In London a chemical process has been applied to the sewage before its discharge into the sea. This consists in adding 3·7 grs. of lime and 2·5 grs. of sulphate of iron to every gallon of

sewage; it produces an average reduction of 18 per cent. of dissolved oxidizable organic matter.

Polarite or magnetic spongy carbon is used at Ealing, Hendon, and other places. The bulk of the suspended and some of the dissolved matter is precipitated by means of "Ferozone" (magnetic ferrous carbon) and the effluent passed through a filter of polarite. The process is said to work efficiently.

The Amines process consists in mixing herring brine (3 grs.) with lime (30 to 50 grs. per gallon) and passing the volatile matters so produced, composed of amines and ammonia into crude sewage which, it is said, is completely sterilized by this means.

All these precipitation processes do, to a certain extent, purify sewage and prevent pollution of rivers, chiefly by removal of suspended matters; but they leave a large amount of putrescible matter in the effluent, certainly all the ammonia (sometimes adding to it); the greater part of the phosphoric acid is precipitated by some of them, while they increase the hardness of river water. The manures they produce are inferior, because the ammonia is lost in the effluent (Corfield).

Mr. W. Webster has proposed to purify sewage by Electrolysis. The chemical change that takes place in sewage when it is electrolyzed depends chiefly on the fact that water as well as the chlorides of sodium and magnesium are split up by the electric current into their constituent parts, chlorine and oxygen being set free at the positive pole, in which they are intensely active, and being liberated in a nascent state oxydize the organic matter in the sewage into innocuous compounds. Cast-iron plates are used as electrodes and give the best results. The effluent produced by this process contains about 3 grs. per gallon of suspended matters, which consist almost entirely of oxide of iron. This is subsequently filtered through filtering beds of sand and coke, and passed on to land, if this is convenient, as it has a certain manurial value. The sludge is passed on to waste land or shipped out to sea.

The Hermite process has recently been tested at Havre, Worthing and other places. This system is based upon the electrolysis of sea-water. The electric current decomposes the chloride of magnesium, while the chloride of sodium serves as a conductor. The result is a liquid disinfectant which is almost odourless and inoffensive. It is claimed for this process that the solid matter in sewage is at once consumed in this solution as well as all organic matter. It is also said that sea-water is not essential to the success of this process; it can be replaced by a solution of chloride of magnesium. Experiments at Worthing show that, although a remarkable reduction in the number of living micro-organisms has been effected, nothing like sterilization has

been produced, since a considerable number of bacteria survive the process.

Intermittent Downward Filtration is defined by the Metropolitan Sewage Commission as "the concentration of sewage at short intervals on an area of specially chosen porous ground, as small as will absorb and cleanse it, not excluding vegetation, but making the product of secondary importance." The intermittency of application is a *sine quâ non*, even in suitably constituted soils, whenever complete success is aimed at.

Filtration may be upward or downward; the former is totally inefficient, and has now been abandoned. The process of purification by filtration is essentially one of oxidation, hence continued aeration of the filter is necessary, which would be prevented by upward filtration. The action of the filter is mechanical as well. As regards the soil itself, the physical conditions, porosity and fineness of division, have more to do with its cleansing power than its chemical composition.

Mr. Warrington has shown that nitrification, *i.e.* the conversion of the organic matter of sewage into NO_3 in the soil depends on the presence of a ferment in the soil; this action is limited to the upper three feet of earth.

The conditions necessary for the successful filtration of sewage are laid down by Mr. Dyke as follows: (1) a porous soil; (2) an effluent drain not less than six feet from the surface; (3) proper fall of land to allow the sewage to spread over the whole land; and (4) division of filtering area into four parts, each part to receive the sewage for six hours, and to have an interval of eighteen hours. He considers one acre of land would take 100,000 gallons per day, equal to the sewage of 3300 people. When properly carried out, this is a valuable method for the purification of sewage.

Irrigation is defined as "the distribution of sewage, over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied." It is essential that the sewage should not merely run over, but through the soil, before passing out as an effluent.

The quantity of land required is large: about one acre to every 100 persons.

To ensure success, the area must be sufficient, the land well drained, and, when necessary, broken up and mixed with ashes, lime, etc., the sewage to be passed on at intervals, so as to permit of aeration of the soil: a succession of growing crops is needed, the ground being laid out in rills and furrows, while the sewage should reach the ground in as fresh a state as possible. If the

land is suitable and the process well conducted, this method for the purification of liquid refuse is excellent.

Simple filtration is sometimes necessary in order to arrest the most offensive matters which, with the street sweepings, can be sold or destroyed in an incinerator.

The Separate System consists in providing separate channels to carry off the rainfall. The advantages claimed for this are that smaller sewers are required, and that the amount of sewer-water is less, richer in quality and more regular in flow; no storm-waters enter the sewers to flood the lower districts of a town, and no road detritus is washed into the sewers. The disadvantages are that separate channels have to be provided, and rain-water washes away much that would pollute a stream; the scouring effect of rain on sewers is also lost, but this is a doubtful objection. Adoption of either plan must depend on local circumstances.

Pneumatic Methods of removing Sewage.—A system, proposed by Captain Liernur, has been carried out on the Continent, where, owing to the situation, any fall for sewerage is not possible. There are two separate sets of drains; the one used for waste-water from houses and factories; the other carries away the excreta from closets and bedroom slops. It is intended that the contents of the former should be allowed to flow at once into any river or stream, as it is only slightly polluted, solid matters having been first separated by strainers, or, if necessary, by filtration. The sewage proper is conveyed by pipes to small reservoirs or tanks placed at intervals along the street; these are made to connect with larger tanks, which, again, communicate with a central reservoir at the sewage works. A vacuum, being produced by an engine working an air-pump at the central works, extends through the whole series of pipes; these are fitted with stopcocks, and the contents of the tanks and street reservoirs are discharged into the central one, from which it is pumped out and manufactured into poudrette. The extracting force is said to equal a pressure of 1500 lbs. per square foot, which is sufficient to draw the excreta through the tubes with great rapidity. This system has the disadvantage of not disposing of waste and slop-waters, for the removal of which sewers are required. There is also the possibility of the pipes being clogged with fæcal matter, and it is impossible to disconnect the house-pipe from the reservoir by an efficient trap. Its success is by no means certain.

The Berlier System is very similar in principle to that of Liernur. The soil-pipe, which is generally 6 or 8 inches in diameter, opens at the lower end into an iron vessel called a *receiver*, within which is an ironwork circular basket, with the iron wires far apart, in which all hard substances and foreign

bodies are retained. Whatever leaves the basket is in a fit condition to travel along the pipes without giving rise to any danger of obstruction. From the bottom of the receiver, the sewage passes into the *evacuator*, to which an exhaust is attached. This works automatically, which is an improvement on the Liernur plan.

The Shone System acts by means of compressed air, and is usually worked from a central steam-engine. The sewage is received into "ejectors," which are cylindrical reservoirs placed beneath the level of the ground, and after a certain quantity has entered, act by means of a float on a counterpoised lever, opening a valve and admitting the compressed air which forcibly ejects the sewage into the further length of sewer-pipe, or to an outfall direct. The compressed-air tubes are conducted along the upper flat outer surface of the reservoir; the arrangement is carried out by valves acting automatically, which permits of the escape of the expanded air as well as the admission of the compressed air. This plan is especially useful when the ground is flat, and it is difficult to get a fall.

Sewer-air.—In well-constructed sewers, where there is no deposit and the sewage is allowed to flow away without any obstacle to the outlets, the air is much better than might be expected. In Carnelley and Haldane's experiments in the main sewer of Westminster and in various sewers in Dundee, the CO_2 was about twice, and the organic matter, estimated by the permanganate process, about three times as great as in the outside air at the same time; while the number of micro-organisms was less in sewer-air than in the outside air, and in smaller number than in the air in any class of house they had investigated. The excess of the CO_2 was probably due to the oxidation of the organic matter in the sewage and in the sewer-air, and, in part, to the diffusion into the sewer from the neighbouring soil. The few micro-organisms present, compared with the external air, is explained by the tendency these have to be deposited on the damp surfaces of the sewers; with ordinary air-currents they are not disturbed or given off to the surrounding atmosphere; those present nearly all came from the outside air, and their number is directly proportional to the number present in the external air at the time. These experiments agree with those recently made by Mr. Laws for the London County Council. He found, as the result of his observations on sewer-air, that the micro-organisms in sewer-air are related to those in the outside air and not to the micro-organisms in sewage, and, *in the absence of splashing*, there is very little ground for supposing that the micro-organisms in sewage become disseminated in the sewer-air. In badly

constructed sewers, or where deposits take place which undergo putrefaction, such favourable results are not found, and disease has been traced to the entry of infected sewer-air into houses through untrapped drains and openings into the drains. Pettenkofer has pointed out the distinction between *sewer-air*, which is generally without smell and harmless, and *sewer-gas*, which is always the result of stagnation, deposit and putrefaction, and recent experiments show the necessity of making this distinction. Ventilating openings should be placed at intervals of 50 to 100 yards along the length of the sewer, so, as far as possible, to equalize the internal and external temperature and barometric pressure. Some of these will act as inlets and others as outlets, while the sewer-air will be rendered so dilute as to be odourless where escaping. In towns these openings should be in the middle of the street, where the air is constantly in motion, and the openings themselves will be as far as possible from the front of houses. In any narrow streets, it may be advisable to carry the ventilating shafts from the sewers above the houses. The entrance of sewer-air or gas into houses is prevented by complete disconnection of the drain-pipe from the sewer by an air-and-water trap as already described.

Comparison of the Different Methods.—Considering all the conditions involved, it appears impossible for all places to adopt the same plan, and the local circumstances of each place must be taken into account in determining the best method for the removal of excreta. The principle to be aimed at is the immediate and complete removal of all kinds of refuse from the vicinity of habitations in the most expeditious manner.

The dry methods do not answer this requirement, as the excreta is only removed at intervals, and although deodorization may be complete, disinfection is not attempted. For a large population, therefore, some system of water-carriage is necessary.

Having, therefore, sewage to deal with, we must get rid of it in the least objectionable manner. It must not be sent into rivers; therefore, where land is available, the immediate application to the land either by intermittent downward filtration or irrigation is indicated.

By intermittent downward filtration sewage can be purified, so that the effluent water may be permitted to run into any stream or river, the water of which is not required for drinking purposes. Little, however, of the manurial value is saved; the greater part passing away in the effluent. Irrigation accomplishes all that is done by filtration, with the further advantage that the whole of the manurial constituents are returned to the soil, which is fertilized by them.

CHAPTER VI.

PERSONAL HYGIENE.

By the term Personal Hygiene is meant the consideration of those matters which concern the person's own health, and which relate only to the individual himself or herself. It includes the discussion of such subjects as Habits, Washing and Bathing, Clothing and Exercise.

Habits.

Our habits may be either important aids to the promotion of health and the lengthening of life, or they may be important predisposing causes of disease.

Eating and Drinking.—It is of the greatest importance that all young people be taught to chew their food carefully and to eat slowly, as quick eaters generally suffer from indigestion later on in life. The excessive use of condiments and spices is a habit not to be encouraged. In youth we may eat plentifully, but in old age we should eat sparingly. The evils of intemperate habits and excess in alcoholic drinks are incalculable. Alcohol, besides rendering man's capabilities for work less, deadens the activity of the mind, interferes with the oxidation of waste matters in the blood, and so alters the character and function of the internal organs, particularly the liver and kidneys, that disease and death therefrom are, in most cases, the early result for those who habitually take alcohol in excess.

Smoking is another doubtful habit, and one for which there is not the slightest reason or excuse under twenty-one years of age. For elderly persons, or those in middle life, particularly when engaged in much mental or other work, the use of tobacco often soothes the brain and otherwise acts sufficiently as a restorative to the exhausted or fatigued nervous system as to justify the continuance of the practice.

Sleep.—The habit of taking sleep regularly is essential to health, for both body and mind need periodical rest, and it is only during sleep that this is obtained. Children need more sleep than grown-up people; small children should sleep at least twelve hours a day, young lads and girls about nine hours and adults about seven hours in a day. Night is the natural time for sleep. If possible, all people should sleep upon beds and bedsteads; to sleep upon the floor and ground is frequently unhealthy, as it interferes with the free circulation of air under and around

the sleeper, and, moreover, favours the inhalation from the floors and ground of gases and vapours, which are best avoided if possible. Plenty of fresh air is wanted at night and during sleep; hence people should not sleep with the head covered up, neither should they lie in draughts and cold currents of air; the body needs to be kept warm at night to avoid chills. All bedding should be kept clean and fresh, as waste matters from the body stick to them and, if allowed to remain dirty, give rise to ill health.

The regular removal of waste substances from the body is most necessary for the preservation of health; for if they are not removed, they become re-absorbed into the blood and there act as poisons. Since the organs by which waste matters are removed from the body are the lungs, the skin, the kidneys and intestines, it is important that all should early acquire habits suitable for keeping them in proper action. The chief agents in regulating the action of the first three are cleanliness and exercise; with regard to the last, the formation of a regular habit early in life is essential, while exercise also helps the action of the intestinal canal.

Another good and important habit is that of cleansing the teeth; this should be done at least twice a day; such a practice, besides keeping the mouth clean and sweet, helps to preserve the teeth themselves and prevent their decay. For those teeth which are decayed, much can be done by going to the dentist, and having the decayed parts cleaned out and "stopped," or plugged, so as to avoid any further extension of the decaying process.

Washing and Bathing.

If the skin is not kept thoroughly clean, the dead scales of it, which ought to be removed, collect upon the surface and, with dirt, block up and check the proper action of the many glands contained in the skin. If the skin does not do its work properly, more has to be done by the lungs and kidneys; and these, if they have too much to do, are likely to get diseased from over-work. The free use of water is an excellent stimulant and tonic to the skin; but to remove dirt and grease and for purposes of cleanliness, bathing or washing without the use of soap and friction is useless.

Soap is either a potassium or sodium salt of one of the fatty acids, stearic, oleic, palmitic acid, etc., produced by the action of either potash or soda upon the fats. As the result of this action of these alkalis upon the fat acids, not only is an alkaline salt of the fat acid formed, that is a soap, but also glycerine is set free. Potash soaps are very deliquescent, retaining so much water

as to form often a soft jelly; of this kind is *soft soap*. Soda soap retains little water, and readily hardens when exposed to the air, constituting hard soap. Ordinary soft soap is largely made from whale or seal oil, and the drying vegetable oils, such as linseed oil. Ordinary hard soaps are commonly made from tallow and the non-drying vegetable fats and oils; their hardness being in proportion to the stearic and palmitic acid which they contain. *Marine soap*, or soap used for washing in sea-water, is made by the action of potash or soda upon cocoanut oil. Cocoanut-oil soap has a great affinity for water, hence frequently gives rise to dishonest practices, whereby fictitious weight is obtained.

Yellow soap is made by a mixture of resin with tallow and palm oil, or with a grease stock consisting of kitchen and bone fat. It is very firm, somewhat rough, and often translucent. *Toilet soaps* are varied in quality. They are commonly made from lard, beef marrow or sweet almond oil, and after repeated refinings by melting and powdering, finally scented with some perfume, such as the oil of roses, bergamot, mallow, lavender, verbena, rosemary, thyme, etc. Their colouring depends upon special pigments added to them. What is called Brown Windsor is an inferior soap of this kind, being made from the residue of refuse fats, scented with nitro-benzene or artificial oil of bitter almonds.

Glycerine soap is merely ordinary soap, to which glycerine has been added. The transparent soaps are made by drying ordinary soap in a stove, and then dissolving it in hot alcohol; subsequently this solution is filtered, the alcohol distilled off and the residue run into moulds. *Silicated soaps* are ordinary soaps mixed with solutions of soluble glass or silicate of soda. These mixed soaps have exceptional cleaning properties, owing to the quantity of free alkali which they contain. Some of the so-called silicated soaps are mere mechanical mixtures of silicious substances, such as fine sand or fullers' earth, with ordinary soap; these are comparatively worthless.

Baths.—Water being a very much better conductor of heat than air, it rapidly abstracts heat from the body if much below the temperature of the latter, which is roughly 98° F. Owing to their physiological action being mainly dependent upon their temperature, the following classification of baths has been made:—

1. Those in which a healthy person feels neither hot nor cold; these are often called indifferent baths. Their temperature varies from 88° to 98° F. Some indifferent baths may be called warm baths, while those intermediate between warm and cold are often spoken of as tepid baths.

2. Cold baths, or those in which a healthy person feels cold.

Their temperature varies from 32° F. to 60° F. If the bath is only moderately long and not very cold, the body heat remains constant, because the production of heat balances the loss. If much prolonged, there is an actual loss of body warmth. Cold baths greatly increase the tissue waste of the body.

3. Warm baths, or those in which a healthy person feels warm. Their temperature may vary from 100° to 150° F. A warm bath increases the body heat by both imparting warmth to it and preventing loss of heat from it. Some people, particularly the Japanese, use very hot baths indeed. Unless one has been gradually educated up to them, exceptionally hot baths should not be employed. Vapour and Turkish baths are varieties of the warm bath. The latter is practically the passing of a longer or shorter time in rooms, at temperatures rising from 100° to 200° F.; during this period, the action of the skin is vigorously encouraged, and the body, after cleansing with soap and friction, gradually hardened by sprayings of water passing from hot to cold, followed by a cold plunge and subsequent rest or detention in a cool room.

A short bath is usually followed by a sense of well being, due to the increased activity of and removal of waste products by the internal organs, consequent on the contraction of the superficial or cutaneous blood-vessels. The feeling of warmth, which so commonly ensues, and ought always to ensue, after leaving a bath, is probably to be explained by a reactionary dilatation of the vessels of the skin after their original contraction. If a bath has been too prolonged, or the person be at all enfeebled, there may be no subsequent feeling of warmth after bathing, due either to the cutaneous vessels not having contracted originally, or that, having contracted, they are unable to expand on leaving the bath, or have become paralyzed by cold. All bathers should take care not to in any way prevent the reactionary dilatation of the superficial or cutaneous vessels, by either remaining in a bath too long or using it at too low a temperature.

Cold baths, if not too cold, are particularly enjoyable, on account of the reactionary exhilaration which follows. Their regular employment is specially favourable for training the capillaries to alternately contract and dilate, and thereby render habitual bathers remarkably free from liability to catch cold.

It is a mistake to bathe either fasting or immediately after taking a full meal; and equally injudicious to do so when exhausted by fatigue. The best time for a bath is either early in the morning after a cup of tea or coffee and a biscuit, or an hour or so after breakfast. Persons advanced in years, and those in whom the circulation is weak, should neither attempt outdoor bathing nor indulge in very cold baths at home; in them the

resisting and rallying powers are often low, and reaction correspondingly difficult to secure. A very hot bath, of 130° to 160° F., is often less depressing than a warm one of a lower temperature, as it stimulates both the skin and circulation. To avoid chills, such very hot baths are best taken at night. The following table indicates the approximate temperatures of water-baths, arranged according to popular designations :—

Very cold	32°	to	50°F.
Cold	51°	,,	60°.
Fresh	61°	,,	75°.
Tepid	76°	,,	88°.
Warm	89°	,,	99°.
Very warm to hot	100°	,,	180°.

It must be remembered that no very precise division of baths can be made, as no two persons are equally sensitive to the effects of heat and cold.

CLOTHING.

The main objects of clothing are: (1) to protect the body from cold, heat, wind and rain; (2) to maintain its warmth, protect it from injury, and also to adorn it. The chief materials used for clothing are derived from animals and vegetables. From the animal world we get wool, fur, leather, feathers and silk; while from vegetable life we draw cotton, flax, jute, hemp, coir, indiarubber and gutta-percha.

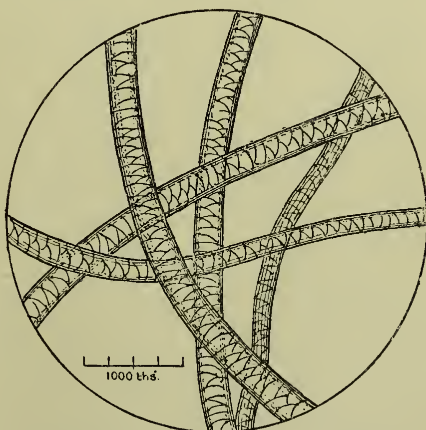


FIG. 64.—Wool under the microscope, taken from white flannel.

Wool is a modified form of hair obtained from sheep, goats, camels and other animals. Wool fibres (Fig. 64) have on their surface fine imbricated scales, which run in one direction and give it a serrated or toothed appearance when examined under the microscope. In the finest wools, these serrations may number as many as 2500 to the inch. Wool is soluble in caustic alkalies, while vegetable fibres are not so. The wool from the Angora goat is known as mohair, and

sawdust & paper are bad conductors

is largely used in the making of plushes, velvets, astrachans and other fancy fabrics. Alpaca comes from the Peruvian sheep, a kind of llama. It is a very fine silky wool and greatly used for shawls and umbrellas. Cashmere is a specially soft and fine wool from the Thibet goat; it is very expensive and difficult to get. Camel's hair is really a fine wool; it is now chiefly met with in the underclothing of Dr. Jaeger. Wool is largely used for the making of flannel, cloth, blankets, worsteds and knitted goods. Felt is really wool made up without either weaving or spinning, the whole holding together simply by the cohesion of the serrated fibres.

Wool is the best material for underclothing; it conducts heat badly, and while absorbing moisture readily, gives it off slowly, so that far less cooling is produced by evaporation from the woollen garment than from any other. It has the disadvantage of hardening and shrinking on washing.

Furs.—These are the skins of certain animals from cold countries, which have in addition to their long "overhair," a dense hairy covering called fur. The chief are bear, seal, chinchilla, ermine, and Russian sable or marten. Fur is often used for making felt; hat felts are chiefly made by compression under heat and moisture of the fur from horses and rabbits. The coarser felts used for carpets are made from cow-hair.

Leather.—The skins of animals, if appropriately prepared by tanning, tawing or shammoying, are rendered tough, yet soft and fit for use by man as clothing. The chief skins so used are those of the ox, sheep, horse and goat. *Tanning* is the steeping of a skin in an infusion of oak bark or other substances rich in tannic acid. By this process, insoluble tannates of the gelatin and albumin of the hides are formed. To be properly carried out, tanning takes nearly a year. *Tawing* is the same process as tanning, except that mineral astringents such as alum and bichromate of potash are used in place of the vegetable product, tannic acid. Tawing is more rapid, but yields an inferior and harsher leather than tanning. *Shammoying* is the impregnating of a skin with fish oil; it is chiefly applied to light skins, and is the process by which chamois leather is prepared.

Feathers are not much used for actual clothing, but rather as ornaments. Their employment is still considerable for stuffing pillows and beds. These latter, if not made too soft and luxurious, are quite as healthy as any other bed.

Silk.—This is the strong fibre produced or spun by the caterpillar or larval stage of certain moths. The silk threads are formed in two small glands situated on the under part of the body and opening by a duct on the lower lip; the silk serves as

a protecting sheath or covering, called a cocoon, for the silkworm when about to assume the chrysalis stage. The silk thread so ejected by each worm and wound into a cocoon, measures some 4000 yards in length and consists of two fine filaments, one from each gland, laid side by side and agglutinated together into a single thread or fibre. The best silk is produced by the larva of the moth called *Bombyx mori*, or Chinese silk-moth. Other kinds of silk are spun from other silkworms closely allied to the *B. mori*. There are the *B. textor* and *B. fortunatus*, common in Bengal; the *B. crœsi*, found in Madras; the *B. arracanensis*, met with in Burmah; and the *B. sinensis*, belonging to China. All these are mulberry feeders. The caterpillar of another moth called *Antheræa pernyi*, found in Mongolia, and which feeds on oak leaves, spins the kind of silk known as tussur silk. The *A. mylitta* is another variety of the tussur silk-moth, common in India. It feeds on bher trees and other shrubs. Similar moths are found in Assam and Japan.

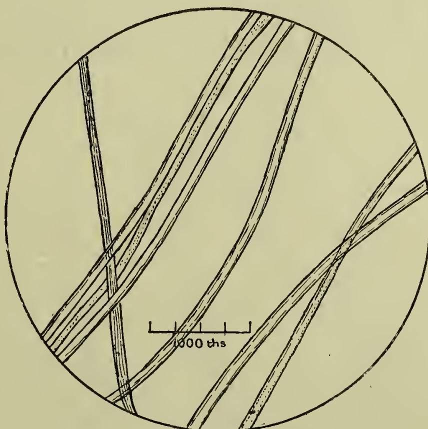


Fig. 65.—Silk from a silk thread.

The silk fibre (Fig. 65) consists of a central core or fibre, covered with a waxy and albuminous colouring matter. Microscopically, silk fibres are structureless and glass-like, usually measuring some $\frac{1}{2000}$ inch thick, and without surface markings or scales. Silk is insoluble in water, alcohol and ether, but dissolves in very strong alkalies, mineral acids and acetic acid. It is readily distinguished from wool or other animal fibre by the action of an alkaline solution of lead oxide, which, owing to the presence of sulphur in wool, darkens it, but does not affect silk. Silk is distinguishable from vegetable fibres by being stained yellow by picric acid, which they are not. The average cocoon yields some 500 yards of workable silk, which in its manufactured form is either reeled or spun silk—this latter being prepared by carding or spinning from the waste and spoiled cocoons. During its manufacture into fabrics, silk fibre is largely altered, expanded, weighted and dyed by various reagents, notably salts of tin and

iron, which render the term "silk," as applied to actual articles of clothing, a more or less conventional expression of what something is meant and ought to be. Silk is mainly used in the manufacture of satins, silks, plushes, velvets, ribbons, crape and in a few woollen goods to give them lustre. Silk is very absorbent of moisture and is a non-conductor of electricity.

Cotton is the downy hair of the seeds of plants belonging to the family Gossypium, of the order Malvaceæ. The cotton fibres consist mainly of cellulose and vary from a half to one inch in length. The fibres are freed from the seeds by machinery, and, after being cleaned and spun into yarn, are woven into fabrics, which, after being bleached, are "finished" for the market. This finishing process usually involves mangling, starching and damping, and often includes filling up the interstices between the fibres with compounds to give weight and a false appearance. Cotton is largely made up into sheeting, calico, towelling, jean, fustian, velveteen, flannelette and paper. When mixed with wool, it constitutes the merino of vests, socks and many fancy materials; it is also mixed with silk or the cheaper kinds of silken goods.

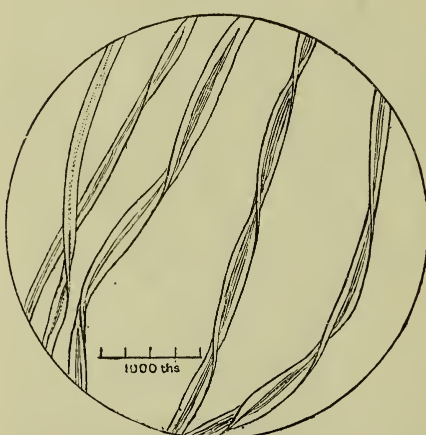


FIG. 66.—Cotton from flannelette.

Cotton filaments (Fig. 66) average about $\frac{1}{1000}$ inch thick, are flat and ribbon-like, and always recognizable by being twisted. Cotton is very durable, does not shrink when washed, absorbs moisture badly, and rapidly conducts heat away. On this account it is ill adapted for under-garments next the skin, as, if perspiration be present, it readily induces chill. What is called "cellular cotton" is merely an ordinary cotton fabric with larger interspaces than usual in its texture. These being filled with air, which is a bad conductor of heat, causes this material to be somewhat warmer than the ordinary cotton.

Flax is a fibre obtained from the stalks of a plant called the *Linum usitatissimum*, which grows to a large extent in Russia and Ireland. The seeds are the familiar linseed, from which the meal of which poultices are made is prepared, and, too, from which

linseed oil and cake, the cattle food, are produced. The stalks, after being allowed to ferment or rot on the ground in the damp, are beaten and combed until something like 6 per cent. of saleable flax fibre is obtained from the plant. The flax fibres (Fig. 67), when seen under the microscope, are marked by transverse striæ at regular intervals; they are not flat like cotton, but more like silk, only they show a fibrous and jointed structure which is not met with in silk. Flax is much more expensive than cotton, and is used chiefly for the manufacture of linen, cambric and lawn. Linen resembles cotton in being a good conductor of heat and a bad absorbent of moisture. It is in many respects even inferior to cotton for underclothing, but from its smoothness and lustre is unequalled as a material for collars, cuffs and shirt-fronts. Weight for weight, flax fibre is stronger than cotton, in the ratio for single yarn of 3 to 1·8, for double yarn as 3 to 2·25, and for cloth as 3 to 2·1.

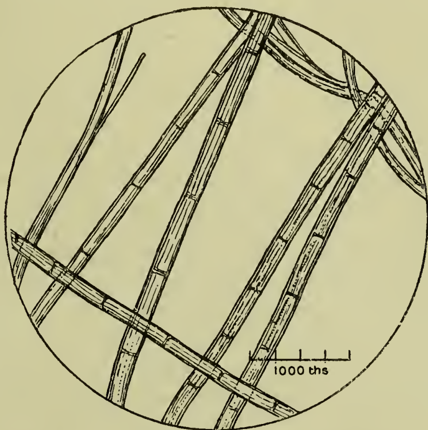


Fig. 67.—Linen, from table-cloth of Irish linen.

Jute is a brittle and very hygroscopic fibre obtained from the *Corchorus capsularis*, a plant growing chiefly in Bengal. Jute is not much used for clothing except as an adulteration of silk and in the making of false hair; it is chiefly employed for coarse fabrics such as mats, cheap carpets, sacking, curtains and table-covers. It is used also as a backing for floorcloths.

Hemp is another fibre not much used in European countries for clothing. It is a coarse fibre, prepared from the stem of the *Cannabis sativa*, a plant growing in Europe, Asia and America. It is prepared like flax and jute, and chiefly used for rope, yarn, canvas packing and sail cloth. The Indian plant yields a narcotic drug, while hemp-seed is a popular food for birds.

Coir is a coarse, tough, harsh, yet light fibre obtained from the husk of the cocoanut. It is rarely used for clothing, but largely so for making mats, brushes and ropes.

Indiarubber enters largely in the present day into the constitution of our clothing, chiefly because it is elastic and impermeable

to water. Under the name of caoutchouc, it is the milky juice of several plants growing in Africa, Asia, and South America. Caoutchouc is a somewhat complex body, dissolving in chloroform, ether, petroleum, benzene and carbon disulphide. Freezing impairs its elasticity, while great heat softens and melts it. Fats also destroy it. When steeped in melted sulphur at 140° C., caoutchouc becomes vulcanized. Macintosh cloth is merely a cotton or silk fabric covered, layer by layer, with a solution or paste of caoutchouc. Guttapercha is, like indiarubber, the juice of certain trees; but these grow only in the Malay peninsula. Excepting as boot soles, guttapercha is little used in clothing.

Warmth and coolness, or the power of maintaining the body heat at its normal height, being the most important property of all dress materials, it follows that our choice of clothing will depend largely upon this feature. How far a given clothing will give warmth depends upon its material, its texture, number of layers and its colour. Owing to fabrics conducting heat in the following order from highest to lowest, namely, linen, cotton, silk, feathers, fur and wool, it follows that wool, fur and feathers are the warmest materials, then silk and cotton, while linen is the coolest. The more readily a material conducts heat, of course, the cooler it feels. This heat-conducting property is mainly proportionate as to how close it is woven, and as to how little air it contains. On this account, all soft, furry fabrics, no matter whether of wool or cotton, always feel warmer than the closely woven, smooth-surfaced silks and linens. In the same way, the more layers of clothing there are, the more layers of air there are retained between them. The influence of colour is dependent upon the heat-absorbing powers of that colour. White absorbs heat the least, and is consequently the coolest; then comes yellow, red, green, blue and black. It is obvious this effect of colour can only be of influence when outside, and that the popular idea that red flannel, when worn next the skin, or as part of an undergarment, is warmer than white is imaginary. It is a mistake to wear coloured clothing next the skin, as not unfrequently the dyes are poisonous, and, coming off, give rise to skin diseases.

While affording warmth, protection from cold, wet and injury, clothing should always be so made as not to in any way impede natural movements, nor unduly constrict any part of the body, nor be needlessly heavy, and also not afford unnatural support. The more we analyze the common forms of clothing, the more we see that their main faults are in the direction of impediment, constriction and weight. This is particularly emphasized in the case of long and close-fitting skirts, tight sleeves, stays, garters, bands

round the waist and neck, ill-fitting gloves, hats and boots. Many of these defects and faults would be obviated if people would remember that (1) no article of clothing should be either so tight as to interfere with the circulation, or so shaped as to change the natural outline of any part of the body; (2) no garment should contain more material than is actually necessary; (3) all garments requiring suspension should be suspended directly or indirectly from the shoulders or hips.

When possible, underclothing should be of wool in this country; in the tropics this is too heavy a material, and linen or cotton shirting is more generally suitable. The Chinese habit of wearing a net next the skin in hot weather, with a thin silken garment over the net, is a good one.

Probably no article of attire is more faulty than the boot. A properly made boot should fit the foot accurately; the great toe should be in a straight line with the inside of the foot; the shape of the sole of the boot should be taken by drawing a pencil round the outline of the foot when the weight of the body is resting on the foot, as in standing, so that the sole may be big enough to support the fully expanded foot; the material should be of soft and flexible leather; even when new, the wearer ought to be able to move all the toes with freedom in the boot; the heel should be broad and low. The stocking or sock should, whenever possible, be of a woollen material or a mixed material in which wool predominates. If no sock be worn, the boot needs to be high and close-fitting round the ankle, so as to prevent dust and stones getting into the boot. The sole of a boot should be wider than the foot, and if the boot is meant for hard wear, the excess of breadth in the sole should be considerable, so as to serve as a protection against loose stones.

Exercise.

It may be said with truth that the chief condition of health is exercise in the open air, and those who have the most of it are the healthiest. The desire for physical exertion and muscular exercise is a natural instinct; the very restlessness of the young child and of school children shows this. Our bodies possess the peculiar attribute that the more they are used, within reasonable limits, the stronger and more vigorous they become. Every one is familiar with the fact that a disused muscle wastes, becomes fatty and wanting in blood, whereas one which is judiciously used and exercised, grows, thickens and becomes in every sense stronger. But mere exercise involves not only growth and development of the ordinary muscles of the limbs, it means

also the healthy use of the heart muscle, of the muscles of respiration, of the muscular tissue of the arteries and of the muscular elements of all parts which are capable of movement. To these must be added an increased activity of the brain and nervous system, along with a stimulation of both secreting and excreting organs.

Upon the circulating system, the effect of exercise is to rapidly increase the force and frequency of the heart's action with a consequential augmented flow of blood throughout the whole body. A healthy heart, during moderate exertion, though often beating rapidly and forcibly, does so regularly and equally; but if embarrassed, or the exercise be severe and prolonged, its pulsations may become small, quick, unequal and irregular. A deficiency of exercise leads often to a weakening of the heart; but, on the other hand, exercise or unaccustomed exercise, suddenly and long continued, may lead to palpitation, valve disease or other heart affections. These may be usually obviated by careful training and judicious rest. Sudden and violent exercise should be avoided by those with diseased hearts, and by those advanced in years, as in them often the circulation is unable to suddenly adapt itself to the new conditions set up.

On the lungs, the effects of exercise are to not only increase the rapidity of breathing, but also to considerably increase the amount of air inspired and the CO_2 expired. Thus, while a man at rest draws into his lungs about 480 cubic inches of air per minute, when walking three miles an hour, he draws in 1550 cubic inches, and if doing six miles an hour, inspires 3260 cubic inches. Simultaneously with this, the amount of CO_2 and watery vapour in the expired air are increased. During exercise, the elimination of carbon is enormously increased, a fact which explains the instinctive desire of men making exertion and not restrained in the choice of food, for the various fats or hydrocarbons with a small amount of starch. When exercise is excessive or badly arranged, the circulation through the lungs may become impeded and the breathing laborious. The knowledge of this fact suggests the need to watch the action of the lungs of all men being trained for prolonged exertion.

Under exercise, the voluntary muscles grow harder and become more responsive to the will. If continuously over exercised, their growth may change to actual wasting, due to damaged nutrition of their fibres, following either the accumulation in them of the products of their own action, or the exhaustion of their supply of oxygen; possibly both.

Provided it be not pushed to such an extreme as to leave no time for cultivation of the mind, there can be no doubt but that

exercise is quite consistent with, and eminently favourable to high mental attainments and activity.

The effects of exercise on digestion are such that it stimulates a desire for meat, fat and salt, and in a less degree one for carbo-hydrates. The abdominal viscera act more vigorously, and the whole digestive processes are increased. The actual amount passed by the bowels during exercise seems to be slightly lessened, possibly due to less water entering the intestines.

Owing to the action of the skin being so much increased during exercise, the water and chloride of sodium of the urine diminishes; on the other hand, the uric acid, pigment and sulphuric acid are augmented. The urea, however, is little affected; while the actual total nitrogen excreted is, if at all increased, only so in the period of rest succeeding exertion.

The exact amount of exercise which a person takes is entirely a matter of individual decision; while what amount a healthy adult should take is not easy to fix, as a hard and fast rule would not fairly apply to all the varying degrees of health and strength.

Work is always expressed in units of weight lifted through a unit of height; as in terms of lbs. lifted a foot, or tons lifted a foot. A fair day's work for a man of average weight and height is generally taken to be about 300 foot-tons, or the work necessary to raise 300 tons one foot high; this has been calculated to be equivalent to walking about sixteen miles in a little over five hours. A hard day's work is about 450 foot-tons, equal to walking some 24 miles in 8 hours; and an extremely hard day's work is from 500 to 600 foot-tons, equal to walking 26 to 32 miles in 9 or 11 hours respectively. For average men, engaged in sedentary occupations, not less than 100 to 150 foot-tons of work or exercise should be performed each day, equal to walking for two hours at a moderate pace, or equal to raising the body-weight through some 500 to 600 yards in height. It is not easy to say what the work done is in mental and office work generally. These rules, it must be remembered, apply only to healthy adults, and need to be much modified in the case of young children, or those whose age or health prevents their exercising their full powers. In children, much of their power and energy goes in building up the growing body, and consequently less exercise or work can be expected of them. Thus, a child, weighing 80 lbs., ought not to be called upon to do half the work done by an adult weighing 160 lbs., but something less, probably in the ratio of the square of their respective weights. In a similar manner, women should not be called upon to do as hard or even harder work than the men.

No mention has been made of the internal work of the body, such as that of the heart, respiration, digestion, etc. This has been variously estimated; but adopting a mean, we get about 260 foot-tons for all the internal mechanical work; which, added to the external labour, makes the demand, for the average person, to be about $\frac{1}{7}$ of all the force obtainable from the food consumed.

Much of our knowledge concerning the work done by human beings, at various speeds of walking, we owe to the Rev. Dr. Haughton, of Dublin, who finds that at about 3 miles an hour, the work done in walking on ordinary roads is equal to $\frac{1}{20}$ of the work done in direct ascent, or that a man walking 20 miles on the flat, at 3 miles an hour, does as much work as if he had raised his body through a mile in height. The fraction $\frac{1}{20}$ is the expression of the resistance due to traction, and varies with the velocity at which the work is performed; being $\frac{1}{38}$ for a velocity of 1 mile an hour, $\frac{1}{26}$ for 2 miles an hour, $\frac{1}{16}$ for 4 miles an hour, and $\frac{1}{14}$ for 5 miles an hour.

When a man goes up a height, he raises his whole weight through the height he ascends, and to compute the quantity of work done we must multiply the weight by the height, and an easy calculation changes this into the weight raised one foot.

The formula for the calculation of work done is usually written thus: $\frac{(W + W^1) \times D}{2240} \times C =$ foot-tons; in which W is the weight of the person, and W^1 is the weight carried, both expressed in pounds; D is the distance in feet; C is the coefficient of resistance or traction; while 2240 is merely the number of lbs. in a ton. The application of this formula will be more readily understood from the following examples.

Let A and B be two men. A lifts a 10-lb. hammer, $4\frac{1}{2}$ feet high, 12,000 times in 8 hours. B, who weighs 10 stone, walks 14 miles on an ascent of 1 in 300 in 6 hours, carrying 30 lbs. on his back. It is required to know which does the harder work, and by how much.

Applying the formula to the case of A, we get $\frac{10 \times 4 \cdot 5 \times 12000}{2240}$ which worked out gives 241 foot-tons of labour done in 8 hours.

B's case is somewhat more complicated. It involves two small calculations, one for the work done, had it all been on the flat, the other for the additional labour involved in going up-hill, which is equivalent to lifting his own and load's weight a given height. The sum of these two will give his actual work done.

Using the formula, we get B's work on the flat to stand thus, after reducing the stones to lbs., and the miles to feet :—

$$\frac{(140+30) \times 14 \times 5280}{2240} \times \frac{1}{20} = 280\tfrac{1}{2} \text{ foot-tons.}$$

As the rise is 1 in 300, we get for the second part of the statement, the lifting of the man's body-weight and load a height of $\frac{14 \times 5280}{300} = 246{\cdot}4$ feet or $\frac{(140 + 30) \times 246{\cdot}4}{2240} = 18{\cdot}7$ foot-tons. Then adding these two results together or $280{\cdot}5 + 18{\cdot}7 = 299{\cdot}2$ foot-tons as the work B does in 6 hours.

In attempting to compare B's work with A's, we must allow for the fact that B does his in $\frac{3}{4}$ the time that A took, or 6 hours as compared with 8 hours. Therefore, to obtain a fair comparison, we must multiply B's work of 299 foot-tons by 4, and divide by 3 or $299 \times \frac{4}{3} = 398$ foot-tons of labour performed by B, while A only did 241 foot-tons, or 157 foot-tons of work done by B more than by A, if both had been working at the same speed.

CHAPTER VII.

INFECTION AND DISINFECTION.

EVERY one is now familiar with the fact that certain common diseases are due to the entrance within the body from without of certain definite poisons or ferments; which, having once entered the body appear there to be able to both grow and multiply. Owing to the poison, after growing and increasing within the body, being capable of being given off again from the body, these diseases are communicable from one person to another, and, as such, are said to be *infectious;* while the actual poison or disease-matter itself is spoken of as the infective agent or *infection.* As the result of improved methods of observation and study, it has, in the case of several of these infectious diseases been possible to recognize and determine that the actual disease producing matters or infective agents are minute forms of life, consisting apparently of a single cell, and that all infectious diseases are probably nothing more nor less than the result of the spreading and development within the human body of these small living cells.

Existing as they do upon the very borderland of the vegetable and animal kingdoms, these minute organisms have given rise to

much controversy, not only as to whether they really belonged to the vegetable or animal world, but also as to what they should be called. It is now very generally recognized that they are minute vegetable cells, though their true position among the plants is still unsettled; and are indifferently spoken of as "microbes," "micro-organisms," "microzymes," "bacteria," "germs," or "contagia." No matter how called, all microbes consist of an external covering of cellulose, and an internal living substance called protoplasm, which is quite destitute of chlorophyll or vegetable colouring matter. It is owing to the absence of this green colouring matter that microbes, though vegetable cells, differ from the higher plants in being unable to decompose atmospheric carbonic acid, in which feature they closely resemble the fungi. On the other hand, they differ from animal cells in having a cellulose covering, and by being able to derive their nitrogen from nitrogenous compounds, such as ammonia and nitric acid.

Microbes vary considerably in form, being either round, oval, rod-shaped, spiral, or filamentous. The round or oval-shaped ones are termed *micrococci;* the rod-shaped, *bacteria*, *bacilli* and *vibriones;* the spiral forms, *spirilla:* while the filamentous forms are generally termed *leptothrix* when straight, and *spirochæta* when wavy. Some microbes are provided with flagella or lashing tails, by which they move, while others are devoid of these appendages. The size of these micro-organisms is, of course, very small; their dimensions, as a rule, varying from about 0·0005 millimetres to 0·05 millimetres in length or breadth; that is, in English measures, something like from $\frac{1}{50000}$ to $\frac{1}{500}$ inch.

Microbes multiply or propagate usually by fission or division, while a few increase their kind by means of spores or eggs. These spores are very resistant to all outside influences, and are able to withstand treatment such as boiling for a few minutes, a procedure which readily kills the parent forms. Warmth and heat favour the growth and multiplication of all kinds of micro-organisms; thus, within an hour, under suitable warmth, a single bacterium divides into two parts, then again in another hour into four, after three hours into eight, and so on until, after twenty-four hours, it has been calculated that the number resulting from a single original one will exceed sixteen millions. It is only by the consideration of facts like the foregoing that the theory and true conception of the nature of infectious diseases can be understood. These diseases are caused and spread by a process resembling the sowing of seed upon a suitable soil, in which, by reproduction of the seed, it, in its turn, becomes a new centre or focus of material whence it may spread and extend to others. A good example of this sequence

of events is seen if we sow a little yeast into a solution of sugar. Yeast, we have already learnt, consists of nothing more than innumerable microscopic plant cells; these, on being placed in the sugar, set up fermentation, by which the sugar is split up into carbonic acid, which goes off into the air and alcohol which remains, while at the same time an enormous increase has taken place in the number of yeast cells. If we substitute for the sugar solution the human body, and for the yeast cell the microbe of an infectious disease, such as diphtheria, enteric-fever, cholera, or small-pox, we can readily appreciate the analogy between the process of fermentation and infectious disease production, and, too, understand that as fresh yeast cells (only too ready to commence their fermenting action) are produced in the sugar solution, so are new disease micro-organisms formed in the body, ever ready, in their turn, to reproduce, on gaining access into another, all the features and peculiar characteristics of their own disease. The close likeness between fermentation and infectious disease processes has led to the term *zymotic* diseases (from *ζύμη*, a leaven) being applied to them. The chief infectious diseases affecting man are cholera, chicken-pox, diarrhœa, diphtheria, erysipelas, influenza, measles, mumps, scarlet-fever, small-pox, enteric-fever, typhus-fever, tuberculosis and whooping-cough.

If the above conception as to the nature of infectious diseases be correct—and there is every reason to believe it is so—that infection matter is living matter in the form of a primitive plant cell capable of growing and increasing within the bodies of men and animals, the course of an infectious disease is truly the life history, so to speak, of a lower plant, and as such has a period of development, a period of its greatest vigour, and a period of decline or death. The time of development, or as it is usually called, the period of *incubation*, is a most important feature in all diseases; so, too, is their duration or length of time during which the sick person is liable to be a source of infection to others. Varying, as they do greatly, an approximate idea of their periods of incubation and infectivity is given in the table on p. 256; but it must not be forgotten that occasionally remarkable exceptions to these averages occur.

The incubation period is that which elapses between actual infection and the appearance of the first signs or symptoms of the disease. In some diseases, as in small-pox, it is almost always of the same length. It is an important fact to know in connection with all infectious diseases, inasmuch it enables us to say, when a person has been exposed to infection, that after the lapse of a certain number of days, if not already attacked, that person is safe and may mix with other people

Disease.	Period of Incubation.	Duration of Infectivity.
Chicken-pox	10 to 14 days	3 weeks.
Cholera	1 to 5 ,,	3 ,,
Diphtheria	1 to 8 ,,	6 ,,
Diarrhœa	1 to 4 ,,	1 to 2 ,,
Enteric fever . . .	8 to 14 ,,	6 ,,
Erysipelas	1 to 5 ,,	1 ,,
Influenza	1 to 4 ,,	3 ,,
Measles	8 to 20 ,,	4 ,,
German measles . . .	6 to 14 ,,	3 ,,
Mumps	14 to 22 ,,	3 ,,
Scarlet fever	1 to 6 ,,	6 to 8 ,,
Small-pox	12 ,,	6 ,,
Tuberculosis	unknown	During the whole disease.
Typhus fever . . .	6 to 14 ,,	4 ,,
Whooping-cough . .	4 to 14 ,,	8 ,,

without risk to them. At present we know very little about the changes which take place in the body during incubation, beyond that the poison is multiplying in some part of the system. The majority of these diseases have a short and limited course, ending either in death or recovery more or less complete. A few, like chicken-pox, mumps and German measles, are remarkably mild in their symptoms; but, on the other hand, a few are liable to vary greatly in their intensity. This is particularly so with both scarlet-fever and small-pox. A general rule seems to be that severity or mildness holds good for the majority of cases occurring in a given outbreak, but that the severer cases are more common in the earlier part of an outbreak than in the latter. Age, sex, race and season, also have an important influence upon the severity of infectious disease attacks. Many curious facts relating to the peculiar action of the causes of these diseases upon the human body could be related; how in some cases only people of a certain age or sex suffer, while in others the attacks and deaths are largely confined to those of certain descent or parentage. These and many other points connected with infectious diseases are still but imperfectly understood.

Perhaps the most important fact in connection with them is that one attack of an infectious disease usually protects the sufferer from a second attack of the same affection. Of course this is not always the case; neither is the duration of the protective action at all constant. In some diseases, such as diphtheria, for instance, its duration is apparently only just sufficiently long to prevent the sick person reinfecting himself. In others it seems to last during the whole of life; in fact, in

Exceptions: - Influenza & Rheumatic Fever

some cases may be transmitted from parent to child. Various explanations have been offered to account for the protection conferred by one attack against a second onset of these diseases; and also to account for the termination of actual attacks. It is difficult to explain the occurrence of most of these affections only once in the lifetime of one person, except on the supposition that in the course of each disease the blood or tissues undergo such a change that they no longer afford, and never will afford afterwards, the conditions necessary for the development of the particular microbe. Whether this change is a removal of some chemical substance necessary for their growth or the production and leaving behind of some direct or indirect product which prevents any further multiplication, or whether the cells and tissues are in some way modified during an attack as to be able to resist future attacks of the same microbe, is by no means clear. Probably other explanations may be given, but it is at least possible that in cases in which any one of the infectious diseases rages with marked violence when introduced into a community that has been long free from it, this may be because the victims come of a stock which has not for some generations been exposed to the contagion. It is considerations like this last which raise doubts in thoughtful minds whether it is either advisable or practicable to keep out infectious diseases by quarantine and other so-called safeguards; because, sooner or later, each special disease would be certain to find its way in, and in all likelihood run riot among populations long free from it.

Vaccination and Inoculation.—The best method of combating infectious diseases will probably be found in the direction of an extension of a practice analogous to that of vaccination against small-pox. This procedure is practically that of inoculating the human being with the lymph or infection juice of small-pox after it has passed through the body or blood of the calf; the result being the infecting of the human body or being with a mild form of disease which, while giving rise to little or no physiological disturbance, renders man more or less insusceptible of true and original small-pox. Based upon the same principle is the well-known Pasteur treatment by inoculation for hydrophobia, or the disease resulting from the bite of a mad dog or wolf. When a person is so bitten, particularly if on the bare skin, he is almost certainly inoculated with the germs or poison of hydrophobia, and which, unless treated by Pasteur's method, generally causes the death of the person bitten. Fortunately, the germs of rabies or hydrophobia take some weeks, often months, and occasionally a year or more, to incubate within the human system before they produce the disease; and when they do develop, they produce in the

infected person or animal a substance which is capable of protecting from a future attack. Pasteur found that rabbits affected with hydrophobia yielded this protecting substance or fluid, and if this were injected into man before the germs from the bite had had time to propagate, the disease could be warded off and prevented from developing itself. Owing to the peculiarly long period which usually elapses between the infection and the outbreak of hydrophobic symptoms, ample time is given for the body to be saturated with the protective fluid before the poison of the disease begins to act and multiply.

In the case of small-pox, the incubation being so much as twelve days, as compared with eight days of incubation for vaccination, it is possible by vaccinating a person within the first three days after exposure to infection to modify and possibly prevent small-pox from developing. Many cases have occurred in which this has been successfully done; thus, suppose an unvaccinated person be exposed to small-pox infection on a Sunday, and be vaccinated on the following Tuesday, the vaccination, if efficiently performed, may prevent the development of the small-pox. If the vaccination were put off till the Wednesday, small-pox would probably appear only mildly and much modified; but if no vaccination took place till the Thursday, then the disease in all probability would develop fully, owing to the vaccine matter being unable to catch up, as it were, the small-pox poison and so affect the system first. Instead of waiting, however, for exposure to small-pox infection to take place before seeking protection by means of vaccination, it is better to be vaccinated beforehand. The law requires every child that is born to be so protected by vaccination before the age of three months—unless, of course, a medical certificate is submitted, stating that a child is not in a fit state of health for it. Some people object to this law as interfering with the individual rights of the citizen; it is not in any way intended to do that, but rather to protect the community or mass of the people from what is a very great danger, namely, the occurrence and increased intensity of small-pox among unprotected persons. In vaccination, carefully and cleanly performed, and with pure lymph, we have an undoubted means of protecting the race against a horrible, loathsome and fatal disease. The apparent failure of so-called vaccination to protect against small-pox is really the failure of imperfect vaccination. The lessons taught by recent outbreaks are too clear to be ignored; they point to the necessity of thorough and careful vaccination in infancy (not less than four good marks or scars are essential for safety), and for revaccination between the ages of 13 and 16, to secure protection against small-pox. It is the sham and imperfect

vaccination which gives a sense of false security, discredits the whole procedure, and acts as a source of danger to society. The experience of Sheffield in 1884, during an epidemic of small-pox, showed that the mortality of the vaccinated children was 31 times less than that of the unvaccinated, on the numbers attacked, and 670 times less on the respective classes living. Similarly, the last report of the Metropolitan Asylums Board, dealing with the year 1892, states that out of the 158 people employed in their small-pox hospitals, two only contracted the disease, one being an assistant nurse and the other a ward maid, on both of whom attempts at revaccination had been unsuccessful. These are facts which require little comment.

There is every reason to hope that in the near future, the principles of this method of infectious-disease prevention may be extended and practically applied to the prevention of other diseases besides small-pox. That, for instance, it may be found possible to pass the contagion of scarlet-fever through some one animal or another, just as small-pox is passed through the calf, so that when re-introduced by inoculation into the human subject, it should induce so little or mild disease as to protect the body against the more serious and true disease. What is known as Haffkine's method of protective inoculation against cholera is an elaboration of this idea, and offers considerable encouragement to others to work upon similar lines in regard to other diseases.

The experiences of daily life show that epidemics or outbreaks of scarlet-fever, measles and other diseases of this kind, vary widely in their severity, sometimes being very fatal ; at other times, though attacking large numbers, yet causing few deaths. The thought naturally arises whether, in these milder outbreaks, the intensity of the contagion or microbe has not been lowered by passing through a number of persons in succession, each of whom was only slightly susceptible to it. Similarly, in the case of the severer epidemics, whether the contagion has not gained intensity by passing through a succession of individuals, each of whom was exceptionally favourable to its development. These are some of the ideas and problems which at present are troubling those whose aim it is to keep infectious disease in check ; their ultimate development and solution are probably but a question of time; but pending this, attention needs to be closely directed to the modes by which infection generally is given off from the sick, and to the means best adapted for its destruction.

Means of Infection.—From what has already been explained, it will be clear that although the causes of certain diseases act

within the body, they really arise from without, and gain access to the body by different ways or methods. The chief means of infection are by air, food or drink, and clothing, to which may be added, in the case of some of the less common diseases, inoculation and absorption by some mucous surface. As regards the reception of infection, it is well established that many diseases are conveyed through the air, and the infection inhaled by the act of breathing. This is the probable means of communication of such diseases as small-pox, chicken-pox, scarlet fever, typhus fever, measles, German measles, whooping-cough, mumps, diphtheria and often tuberculosis, also of certain infectious forms of inflammation of the lungs.

It is not quite clear how far air receives its infectious qualities from the breath of persons infected with diseased throats, or by exhalations and the desquamated particles from the skin, as in typhus, small-pox and in scarlet fever. In any case, infection through the air presupposes the existence of microbes, or their spores, in a more or less dry state, floating about as impalpable dust; conditions which we know are not inconsistent with their vitality. Little is known as to the precise distance to which infection can be carried through and by the air. Experience goes to show that scarlet-fever and typhus can only infect at short distances; that whooping-cough and measles can do so at greater; while the occurrence of a radiation of infection round the Fulham Small-pox Hospital, in 1884–5, indicates the possibility of small-pox infection at long ranges, the number of cases infected therefrom diminishing as the distance from the hospital increased. It is necessary, however, while attaching importance to these hospital experiences, not to overlook the possibility that many of the cases were spread by personal intercourse, particularly as some laxity existed in the regulations controlling the access of tradesmen, friends of the sick and others, to the building. Food and drink, especially water and milk, are known to convey the poison of enteric fever, cholera, diphtheria, tuberculosis and even scarlet fever; the germs being in such cases swallowed. Carelessness, and want of cleanliness of the hands have been the cause of carrying infective matter to the mouth, notably in the case of those tending upon the sick; while clothing is a most notorious aid and means for the harbouring, preserving and conveyance of microbes, germs, contagia and the like. A few diseases such as glanders, anthrax, erysipelas and some of the parasitic skin diseases are more often than not transmitted by either direct contact, or inoculation. In no case can any hard-and-fast rule be laid down as to the precise mode by which any particular infectious disease is communicated to another; whether

by means of air, food, drink, personal contact, inoculation, or clothing. Many of these affections are transmitted by one or more of these ways. Inoculation and absorption are the rarer means of infection; but are very generally associated with the occurrence of such diseases as hydrophobia, glanders and anthrax, which are distinctive as being common to both men and animals.

Small-pox is infectious from the very commencement of the disease, the infection gaining intensity as the eruption advances, even up to and including the scabbing stage. The microbes or germs of the disease are contained in the secretions of the nose, mouth and air passages, as well as in the contents of the pustules or pocks. They are given off most freely, when these latter dry and scab, diffusing themselves to great distances in the form of a fine dust. Owing to the great resisting power or vitality of these microbes, the spread of small-pox by means of infected clothing is even greater than that of scarlet fever. Individual protection against an attack of small-pox can be obtained in three ways: by natural small-pox, by inoculated small-pox, and by vaccination. In former years, protection once acquired was looked on as permanent and absolute; but later experience shows that from whatever cause obtained, the amount of protection varies according to the thoroughness of the protective procedure. Severe small-pox gives more lasting protection than mild small-pox; small-pox inoculation gives most protection when followed by an eruption; and a complete, thorough and multiple vaccination gives more lasting protection than does a vaccination in which only a single small vesicle has been produced.

At the present time, a second attack of small-pox is less frequent than formerly, because as a result of the practice of vaccination, a first attack of the disease usually comes later in life, so that the protection it affords does not wear off in time to readily allow of a second attack.

Protection from small-pox by deliberate inoculation of the disease, or variolation, as it was called, was very generally practised in this country during the last century, and until made illegal in 1840. The chief objections to it were the danger to life which attended it, the disfigurement which so generally followed, and the fact that the inoculated went about spreading the disease broadcast. The researches and observations of Edward Jenner, between 1768 and 1798, led to the introduction of vaccination, or the inoculation of man with the small-pox of the cow, by which man contracted the affection called *vaccinia*. This vaccinia is, as Jenner always supposed it, small-pox of the cow; but owing to the remarkable change in the cow or calf of small-pox into vaccinia, the poison of human or ordinary small-pox is so

weakened as to be unable to cause, except in rare cases, a general eruption or to spread by atmospheric convection; in fact, to use the words of Dr. McVail, the change in the calf from small-pox to vaccinia has the effect of "removing the objectionable and retaining only the valuable part of the original disease. Following the introduction of vaccination, there has resulted a remarkable decline in the prevalence of small-pox, not only in England, but in various European countries. This decline, it has been urged, was due, not so much to the use of vaccination, as to the decrease of inoculation and to increased attention to sanitation. That the mere decline in the practice of variolation was not the cause of a diminished small-pox prevalence is well shown by the experience of Sweden and Copenhagen, where it so happened inoculation for small-pox was never largely practised; yet the death-rate from small-pox per million of population was in Sweden, in the last century, no less than 2050, and now since the introduction of vaccination the death-rate is but 158 per million; the corresponding figures for Copenhagen are 3128 and 286. As bearing on the question of the influence of sanitation as a factor in the decline of small-pox, it has been pointed out by various writers, principally by Dr. McVail, that the statistics of all diseases teach that in reference to sanitation each disease has to be considered by itself. Though the removal of fæcal impurities has diminished enteric-fever, it has not affected measles. The lessening of overcrowding and personal filth has much lowered the typhus-fever rate, but without reducing the diarrhœa rate. Vaccination has diminished small-pox without similarly affecting whooping-cough, and while general cleanliness and purity of water and food are useful against all diseases, yet "the lessening of small-pox cannot be set down to improved drainage any more than can the lessening of enteric-fever be set down to vaccination" (McVail).

The remarkable diminution in the small-pox death-rate since the introduction of vaccination is shown in the following table of small-pox deaths per million of people living in England and Wales.

Years.	1838–1840.	1841–2 and 1847–9.	1850–1854.	1855–1859.	1860–1864.	1865–1869.	1870–1874.	1875–1879.	1880–1884.	1885–1890. 6 years.
Death-rate per 1,000,000	771	295	279	199	191	148	433	82	62	28

During 1855–64, when vaccination was optional in Scotland, the annual death-rate from small-pox was 340 per million of inhabitants; but when vaccination was made compulsory the

death-rate dropped to 80 per million for the years 1865–90. Dr. Edwardes gives some interesting figures from Sweden, where the small-pox statistics go back to 1774. From that date to the beginning of this century the average annual death-rate was 2008 per million of people. From 1801 to 1815, vaccination was optional, and the death-rate fell to 631. In 1816, vaccination became compulsory in Sweden, and during the period 1816 to 1885 the death-rate has been 173 per million; while for the last eight years of that period it has been but 41 per million.

Perhaps the strongest argument in favour of the view that it is vaccination and not sanitation which has so reduced the prevalence and mortality of small-pox of late years, is the fact that in pre-vaccination times small-pox was very largely a disease of childhood, while now, owing to infantile vaccination, the main incidence of the disease has been transferred to later periods of life. That this is the case is shown by the following table, taken from the First Report of the Vaccination Commission, p. 114, and which indicates the mean annual deaths from small-pox at successive life periods.

Period.	All ages.	0–5.	5–10.	10–15.	15–25.	25–45.	45 and upwards.
Vaccination optional, 1847–53	305	1617	337	94	109	66	22
Vaccination obligatory, but not efficiently enforced, 1854–71 . .	223	817	243	88	163	131	52
Vaccination obligatory, but more strictly enforced, 1872–87 . .	114	242	120	69	122	107	47

The same lesson is taught even more strikingly by noting that in the present day, small-pox among the unvaccinated still selects its victims principally from the earlier ages; this being observable in statistics from all countries. The following table is based on the Registrar General's records for England and Wales for the ten years 1881–90, and shows the proportion per 1000 small-pox deaths.

Age.	Vaccinated.	Unvaccinated.	No statement.
Under 15 years . .	242·8	710·6	416·4
Over 15 years . .	757·2	289·4	583·6
Total . . .	1000·0	1000·0	1000·0

No such change of age incidence is to be seen in any of the other zymotic diseases, as is found to have taken place with respect to small-pox since the introduction of vaccination.

Much valuable evidence has been collected of late years in regard to the duration of the protection which vaccination gives against small-pox. This evidence indicates that although the susceptibility to the operation of vaccination returns comparatively soon after a primary vaccination, the susceptibility to small-pox returns but slowly; so slowly, in fact, that the power of infantile vaccination against attack by small-pox may be said to remain at least to one-half of its original extent at twenty years of age. On these points the evidence given by Dr. Gayton before the Vaccination Commission (Second Report, p. 245) is peculiarly interesting. He found that some 40 per cent. of vaccinated children could be revaccinated at the age of from six to ten years; but of vaccinated children of the same age exposed to the infection of small-pox by residence with cases of the disease, less than 10 per cent. were attacked, though under the same exposure no less than 92 per cent. of unvaccinated children of the same age contracted the disease. If we compare the attack rates under exposure with the fatality rates among attacked persons in successive age periods from birth upwards, as shown by the statistics of the great small-pox hospitals, we find that resistance to death by small-pox among the vaccinated outlasts very considerably resistance to attack by small-pox, and also that the inclination to both attack and death by small-pox is much slower in course and much less in ultimate amount in the well vaccinated than in the badly vaccinated.

Some people profess to be much opposed to the practice of vaccination, and in support of this view allege that (1) vaccination neither prevents nor modifies small-pox; (2) that it gives rise to other diseases; (3) that it is unnecessary, as small-pox is only slightly infectious, and can be prevented by isolation in hospitals. No one who has studied the statistics, nor any one who has read the few facts explained above as to the real nature of the case, can for one moment honestly believe or think that vaccination neither prevents nor modifies small-pox. The truth is vaccination does both. With regard to the second contention, that vaccination gives rise to other diseases, much untruth has been both written and spoken by prejudiced persons. The facts appear to be that in a very small percentage of cases, certain diseased conditions have resulted either from or in consequence of vaccination having been performed. But when these cases have been closely inquired into, it has been found that grave errors had been committed in the performance of the operation, and that due

precautions had not been taken in the choice of the source of the vaccine lymph. Considering the enormous number of vaccinations that have been performed during the past fifty years, it is remarkable how few genuine cases have occurred in which disease has in any way resulted from the procedure. It is probable that with an increased use of vaccine direct from the calf, and the exercise of greater care even than has hitherto been exercised, the alleged risks of vaccination in this direction will quite disappear. Coming now to the third objection to vaccination, or the statement that it is needless because isolation is a better preventive than it, we find that on this particular allegation there is practically no evidence at all. What evidence there is, is based upon the experience of Leicester, in which town isolation of the small-pox sick has been very rigidly carried out. But this town is not an instance where isolation has been employed as a *substitute* for vaccination, because the great bulk of the inhabitants of Leicester have been vaccinated at some time or another, with the result that the experience of Leicester really only amounts to an experiment as to the efficacy of isolation, *plus* a certain amount of vaccination. Moreover, the doctors, nurses and attendants of these isolated small-pox sick are all vaccinated individuals, which means simply that the patient has around him a cordon of protected or insusceptible people. Surrounded in this manner with persons protected from the disease, it is not remarkable that diffusion or communication of the affection has been small; but were the immediate attendants not thus protected by either vaccination or revaccination, it may be absolutely affirmed that isolation alone, as so understood, would rapidly result in an overwhelming increase in the numbers attacked with the disease.[1]

Chicken-pox.—This, though usually a very mild disease, is, without doubt, infectious. The eruption appears without any previous sickness, commencing on any part of the body, and is added to irregularly by fresh crops of vesicles for four or five days. As in small-pox, the length of the period of its infectivity depends upon the falling off of the scabs or crusts. Assuming that the incubation period of chicken-pox is a fortnight, a detention under observation or quarantine for eighteen days should be insisted upon in the case of all children after exposure to infection by this disease before they return to school or mix with their fellows.

[1] Those further interested in this important subject should consult "Vaccination Vindicated," by J. C. McVail, M.D., published by Cassell and Co., 1887; also "Vaccination and Small-pox in England and other Countries," by E. J. Edwardes, M.D., published by J. and A. Churchill, 1892.

Scarlet Fever.—In this disease the infection reaches the air in the early stages, even before the rash appears, chiefly by the breath and mucous secretions of the nose, mouth and throat. Later on, it is given off by the skin as well as by the breath, particularly in the form of fine bran-like scales of skin. Fortunately, these do not appear to spread infection any great distance through the air; but, on the other hand, they lend themselves so readily to attachment to clothing that infection is retained for months, long after the original case existed. On this account, too great care cannot be exercised in burning, or, at least, adequately disinfecting, by some means or other, to be presently described, all handkerchiefs soiled by the nose and throat secretions, as well as all bedding and clothing which has been exposed to infection by the sick person. Until recently the above means of dissemination, namely, by immediate infection from a human case or indirectly by means of clothing, was regarded as the only possible method for the spread of scarlet fever. The remarkable inquiries made by the Local Government Board in a series of epidemics of this disease associated with certain dairies and milk supplies, combined with the results of Dr. Klein's investigations thereon, have, however, shown beyond doubt that human scarlet fever may be produced and spread by milk, which owes its infective property to a disease of the cow, and quite independently of any possible infection from a human source; though, in the majority of such milk epidemics of scarlet fever, the infection of a particular milk supply is from human scarlatina. These facts constitute a good reason why milk should be boiled before use. There is no evidence of scarlet-fever infection being conveyed by water, nor of its being carried any great distance by air currents.

Diphtheria.—This is another disease largely diffused by the air, more particularly at short distances. The reason being that the microbes of the affection swarm in the exudations and secretions of the nose, mouth or throat, and infection readily follows the inhaling, swallowing, inoculation or absorption of any of them. The vitality of the micro-organisms of this disease is great, so much so, that they can survive long periods of time when attached to, or hidden away in clothing. There is reason to believe that much of the spreading of this affection is due to the crowding together of susceptible persons, such as children in schools where the inadvertent presence of a single unrecognized case in its earliest stage is sufficient to infect, by means of the breath, many others. Besides an influence due to general dampness of the soil, there is a considerable amount of evidence in favour of the view that special and continuous dampness of

the dwelling-house materially aids the production of diphtheria. One of the most striking facts in connection with outbreaks of this disease is, that they are so frequently preceded by a more or less widespread prevalence of cases of sore throat, varying much in severity. So often have outbreaks of true and typical diphtheria, following minor throat illness, occurred in particularly isolated places and under conditions which exclude the likelihood of their having resulted from any importation of the infection from elsewhere, that an idea has grown that possibly ordinary sore throats may be able to acquire a progressive degree of the property of infectiveness. At present there is no precise knowledge as to the fact of this actually taking place; but it is suggestive of the need to correct any faulty sanitary conditions of schools and other buildings which may in any way tend to ill health. In connection with the sudden appearance of diphtheria in isolated localities, the question of conveyance by the air or otherwise arises. The experience of the behaviour of diphtheria in houses and hospitals shows that its infection is readily conveyed through the air of rooms for short distances, and to those in close actual contact with the sick; but there is little evidence in favour of the view that the diphtheria contagion can travel very far and yet retain its virulency. It is much more probable that the infection can be, and is, transmitted from place to place by adhering to clothing and persons, or even to animals and food. The facts connected with more than one outbreak of diphtheria among children and adults have shown the existence of a concurrent throat disease among domestic animals and birds, more particularly cats, sheep, horses, cows, fowls, turkeys and pigeons. The investigations of Dr. Klein, reported to the Local Government Board, indicate that cats have diphtheria, and that cows can suffer from an ailment so slight in appearance as to be unnoticed by the dairymen, but capable of imparting infective qualities to the milk which give rise to diphtheria among those consuming it. Hence, another reason for boiling milk before use.

For many years it was thought that accumulations of filth and drainage defects were the direct cause of the origin and spread of diphtheria. In the light of more recently acquired knowledge, there is reason to think that this older belief must be modified, and that the true part which insanitary states play, is by way of predisposing to infection by lowering the standard of health rather than by being the actual origin of the disease. As in the case of scarlet fever, there is no evidence that diphtheria is spread by the agency of drinking-water. Some have said that the diphtheria germ can find a resting-place, in which

it can long survive, in the surface soil, and that a rise in the subsoil-water, by expelling the ground-air, leads also to the expulsion of the micro-organisms and so originates some of the outbreaks of this disease. At present there is nothing definite known on this point, though a considerable number of facts have been collected which lend some support to this view of the relationship between the fluctuations of the ground-water with diphtheria prevalence.

Diphtheria outbreaks are noticeable for being associated frequently with cases of so-called "croup," and with a series of antecedent cases of scarlet fever. Some doubt has long existed as to the precise meaning of these associated cases; the true explanation probably is that what is called croup is oftener than not unrecognized diphtheria or, at least, a form of laryngitis. In the other association, it is probable that scarlet fever leads to more or less temporary damage to the mucous membrane of the throat, and in this manner predisposes to the reception of the diphtheria poison, causing a series of diphtheria cases to follow after a series of scarlet fever cases. Both diseases appear to be more prevalent during the autumn and winter, than during the spring and summer. During 1892, the deaths from diphtheria in England and Wales were in the proportion of two hundred and twenty-two to a million persons living.

Typhus Fever.—In former years, this disease was much more prevalent than now. It is very rarely met with in the present day, except in the poorest, dirtiest and most overcrowded parts of towns. Its diminution is attributed to the removal of personal filth and overcrowding. The infection of typhus is largely communicated by air, though only at close quarters; being much weakened by air diffusion and dilution, that is, by ventilation. It occasionally is transmitted by means of clothing. It is only within comparatively recent years that typhus-fever has been clearly distinguished from other fevers, notably enteric-fever and relapsing fever.

Measles, Whooping-cough, and Mumps.—These diseases have their infective germ contained almost exclusively in the mucus of the nose, mouth and throat, or in the breath. They are all apparently very infectious, even in the earliest stages, the contagion or germ being capable of spreading, not only by the air, but by clothing, such as handkerchiefs, pillows and bed-linen. What is known as German measles is a malady seemingly different from scarlet fever and measles, but having some of the characters of both. It is regarded as an entirely distinct disease, inasmuch as it occurs in epidemics, is able to protect against itself, but not against either scarlet fever or measles; nor do attacks of either of

these diseases protect against it. Like measles and whooping-cough, German measles is contagious even before the rash comes out; fortunately, it has little or no mortality, and its power of infection is less active and less persistent than those of either measles or scarlet fever. Owing to their early infectiveness, all these diseases spread largely by the attendance of children at schools and other places of public gathering, who are merely sickening for them, and have not so far manifested the characteristic symptoms. There is no evidence that these diseases are ever disseminated by the agency of water, milk, or even by domestic animals.

Tuberculosis.—This is a diseased condition which occurs in man in a variety of different forms, the most familiar being phthisis or consumption, scrofula, and meningitis. Tuberculosis is not limited to the human race; it is very common among oxen and cows as a disease known as "grapes," it also affects pigs as well as fowls, rabbits and guinea-pigs. It is causally related to the action of a particular bacillus, and the existence of these bacilli in the expectoration of those afflicted with consumption or tuberculosis of the lungs, suggests the communicability of this disease from one person to another, particularly by means of the air. That this is true in fact, has been shown by the collection of numerous instances of the infection of whole groups of people, free from all hereditary taint, by mere residence in rooms or houses which had been previously occupied by persons suffering from tuberculosis. The infective microbes of consumption exist only in the expectoration, and are not given off by the breath of those suffering from this disease. This fact prevents their being spread through the air so long as the medium which contains them is moist; but once the expectoration becomes dry, then the germs are easily raised by draughts and scattered about as dust, in which form they gain access to the lungs. This sequence of events is very liable to occur when consumptive persons are allowed to spit upon floors or into handkerchiefs; but can be readily obviated by insisting upon all such affected persons spitting into spittoons which contain a little water, the contents afterwards being either burnt or buried.

Every one knows that tubercular disease is peculiarly liable to occur in different members of the same family, and this often through succeeding generations. These facts are not altogether to be explained as being a consequence of either direct or indirect infection; it is more probable that heredity is largely to be held responsible. In addition to direct infection by the inhalation of dust laden with the dried spores of the tubercle bacillus, and to the influence of inherited predisposition to the tuberculous

Fumigating by Chlorine = 1½ - 2 parts Hydrochloric

infection, there are other causes which largely conduce to the prevalence of this disease. Among these are all unhygienic conditions of the dwelling or workshop; such as dampness, defective ventilation, overcrowding, and the inhalation of mechanically irritating dust particles, as in the case of the various dusty trades.

Possibly of the first importance in regard to the spread of tuberculosis is the subject of its relation to food. This involves, not so much the question of how far deficient and indifferent food indirectly predisposes, like other insanitary circumstances, to tubercular infection, but how far food serves as an actual and possible carrier of the tubercular bacillus or germ. It has already been stated that cattle and other animals suffer from tuberculosis, and although the full identity of their sickness with that of the similar disease in man has not been absolutely settled, it has been sufficiently so demonstrated to indicate that the risks of infection through this source are grave. This infection may be either through meat, or by milk; and the evidence as to the possibility of either of these contingencies is sufficiently strong for us to condemn as unfit for food all parts of the carcase of a dead animal in which signs of tubercle are manifest, and even condemn the whole carcase if the disease be far advanced and the beast emaciated. Possibly it would be wiser to condemn absolutely the whole carcase if there be evidence at all of tuberculosis in any part, no matter how limited in extent. There is ample experimental evidence to show that tubercle bacilli are present in the milk of tuberculous cows, and may even be present in the milk when the teats of such cows are unaffected with tubercle; further, that even when no bacilli are found in such a milk, the feeding of young and healthy animals with it, gives rise in them to tuberculosis. The heat employed in cooking meat is insufficient to destroy the bacilli present in its deeper parts; but, fortunately, the danger of tubercular infection by milk is obviated by boiling, and this precaution, on this account, should be invariably adopted, especially when it is to be used for the feeding of children.

Influenza.—The recent series of epidemic visitations of this disease in this country have made its chief characteristics familiar to most people. Although the original home of this affection is not known, our knowledge is sufficient to convince us that it is a disease which has periodically prevailed in various parts of the world since very early times; and also that a particular micro-organism stands in causal relation to it. Influenza is remarkably infectious even in quite the early stage. Our knowledge as to how this disease originates and spreads is small; but what we do

know indicates that its progress is quite independent of season or weather; that man is the chief vehicle of its diffusion; and that its epidemic prevalence attains its height amongst crowded communities. The curious tendency of influenza to recur at intervals in the same locality is suggestive that the contagion or germ may be able to live and thrive for considerable periods outside the human body; but whether this is in the soil or in the bodies of domestic animals is unknown. That these latter creatures suffer during influenza epidemics from symptoms extremely like it is generally accepted. If similarly circumstanced, both males and females appear to suffer equally from influenza; its mortality is greatest in the middle and later periods of life, and especially among those weakened by disease or at all predisposed to bronchitis and pneumonia. Experience indicates that the ordinary preventive measures are of little or no avail.

Erysipelas.—This has been defined as a spreading inflammation of the skin, accompanied by fever. It is met with all over the world, but less frequently in the tropics than in more temperate climates. From facts, collected by Dr. Longstaff, erysipelas has a mortality in inverse ratio to the rainfall, in this respect resembling scarlet-fever; it affects all races alike, and is especially fatal among the very young. Formerly it was usual to regard erysipelas as occurring either through a wound or without. To a large extent this distinction has been replaced by the belief that every case is caused by the poison entering the system through a wound, though this in some instances may be so insignificant as to be overlooked.

The actual cause of erysipelas is without doubt a micrococcus; it is certainly an infectious disease, but somewhat variable in its infectivity. It at times runs riot in hospitals, especially in surgical wards, the most important favouring circumstances being defective ventilation, overcrowding, want of cleanliness and defective drainage arrangements. Some people seem to be more predisposed to erysipelas than others, among such are the intemperate, the badly fed, and those who have had it before. Our knowledge at present is small as to what are the precise connections between erysipelas and the various forms of blood-poisoning, more particularly that peculiar kind of blood-poisoning associated with lying-in women or those recently confined. Evidence is strong that there is a relationship of some kind between erysipelas and child-bed fever, as shown by the familiar fact that women in labour attended by doctors or midwives who are suffering from erysipelas, or even have been in contact with erysipelas patients, commonly get blood-poisoning or child-bed fever. Similarly nurses, midwives and doctors who attend, or come into close

contact with women suffering from blood-poisoning frequently themselves suffer from erysipelas; also that the newborn children of mothers with child-bed fever die in large numbers of erysipelas. To a less degree, erysipelas has some obscure relationship to diphtheria prevalence. During the five years, 1888–92, the average annual death-rate from erysipelas per million persons living was 48.

Epidemic Diarrhœa.—This is essentially a disease of towns and crowded areas; its incidence being greatest upon young children below two years of age. Outbursts of epidemic diarrhœa occur nearly every year, the most usual season being in the months of July and August. The chief facts concerning the prevalence of this form of disease may be summarized in the terms of the results of Dr. Ballard's inquiry into its causation as explained in his Report to the Local Government Board in 1887.

Elevation of site influences diarrhœal mortality only in so far as it affects infant mortality, from all causes.

Soil.—Loose porous soil is most conducive to mortality from diarrhœa; particularly if coupled with organic fouling of the earth, no matter whether vegetable or excremental. Diarrhœa is prevalent upon sites such as "made soils," or on ground polluted by drain or cesspool leakage. Both excessive wetness and excessive dryness of soil seem to lessen diarrhœal mortality, but a moderate dampness of soil favours it.

Temperature.—The mortality from diarrhœa is usually high when the air temperature is high, but this is only indirectly so, because the highest mortality coincides less with the highest readings of the air-thermometer, than it does with the thermometers in the soil. The summer rise in the diarrhœa death-rate does not commence until the mean temperature of the 4-foot soil-thermometer has reached 56° F.; no matter what heat may have been recorded by the air and 1-foot soil-thermometers. The maximum mortality and decline in the diarrhœa rate coincide with the mean weekly maximum and decline of the temperature recorded by the 4-foot earth-thermometer.

Rainfall exerts little influence, except by its effects upon soil-temperature. The diarrhœa death-rate is greater in dry seasons and less in wet ones.

Wind lessens the mortality, but calm, stagnant days promote it.

Social Position.—The diarrhœa prevalence and death-rate are notoriously greatest amongst the very poor.

Want of cleanliness has a similar influence, and is, too usually associated with poverty.

Foul air from sewers and cesspools, and accumulations of filth, favour diarrhœa mortality, while smoke and chemical effluvia are inoperative.

Undefined foulness of drinking water is not responsible for ordinary epidemics of summer diarrhœa, though it may occasionally produce a few cases.

Want of ventilation and light are particularly conducive to diarrhœal mortality; especially associated as it is with overcrowding, back-to-back houses, dark courts, alleys and streets.

Density of Buildings upon an area, irrespective of density of population, materially increases the tendency to diarrhœa.

Food is closely concerned with the epidemic prevalence of diarrhœa, not by causing ordinary indigestion, but owing to its being contaminated with some substance, "which substance is by itself an efficient cause of the malady." The mortality is very high among the artificially or bottle-fed children; the breast-fed infants being remarkably exempt.

Maternal neglect conduces to much infant mortality; this is specially seen in the greater mortality among illegitimate children as compared with the legitimate.

The occupation of females from home, by conducing to neglect and artificial feeding of infants, promotes diarrhœal mortality.

Upon these and other observations Dr. Ballard makes the inference "that the essential cause of epidemic diarrhœa resides ordinarily in the superficial layers of the earth, where it is intimately associated with the life processes of some micro-organism not yet isolated."

"That the vital manifestations of such organism are dependent, among other things, perhaps principally upon conditions of season, and on the presence of dead organic matter, which is its pabulum."

"That occasionally such organism is capable of getting abroad from its primary habitat, the earth, and having become air-borne, obtains opportunity for fastening on non-living organic material (especially food, whether inside or outside the body), which serves as a nidus and pabulum."

"That from food and from organic matter in certain soils it can manufacture a virulent chemical poison which is the material cause of epidemic diarrhœa."

As already stated, diarrhœa, particularly in its epidemic form, is very fatal to infants, among whom it produces a mortality of about 25 per 1000 of births. The mortality lessens from infancy to 20 years of age, after which it increases again, being particularly fatal in extreme old age. Certain towns, notably Preston and Leicester, enjoy an unenviable notoriety for their very heavy

mortality from epidemic diarrhœa every year. Most other large towns suffer in the same way each summer, but in a less degree.

A distinction must be made between the epidemic diarrhœa indicated in the foregoing and certain epidemic outbreaks of diarrhœa which occasionally occur in public institutions. These latter can usually, upon investigation, be traced to articles of food or drink, especially water, when containing excess of mineral salts, sewage or vegetable matter. Similarly, milk and butter, or cheese, may give rise to diarrhœa, owing either to fermentative changes in themselves or to fouling by some specific gas. Tinned meats, pork pies, ham and game, or even fish, have on several occasions been traced as the ultimate cause of extensive diarrhœal outbreaks. In these cases, the poison partakes of the nature of a chemical body, the product of putrefactive changes in the food stuff, and is altogether unassociated with the climatic conditions hitherto considered.

Enteric Fever.—This disease is often called typhoid fever, and by some Continental writers spoken of as abdominal typhus. It is frequently prevalent in this country, especially during the autumn months; its average annual death-rate per million living for the five years, 1888–92, having been 164. True enteric fever appears to be rare among infants and young children; it is most prevalent in youth and adolescence, the cases becoming fewer and fewer after the age of thirty. Judging by the average severity of attack, more females die from it than males, the figures being 18·8 per cent. of deaths for female cases, and 17·1 for male. As with many other infectious diseases, enteric-fever appears to confer a protection against a second attack; its incubation period is long, and its course exceedingly variable. Enteric fever is closely associated with a micro-organism, and is essentially a communicable disease. It is now well established that the poison or infection of this disease is given off from the body of the sick person in association with the bowel discharges, and it is these which are so infectious. Air does not appear to carry the enteric-fever poison under ordinary conditions; though when clothing, bedding and other objects have been soiled by the enteric discharges, and these have been allowed to dry and pulverize, there is no reason to doubt but what an active dissemination of the disease infection may result by aerial diffusion of dust particles. The most common means by which the infection of enteric fever finds its way into the body of another is by way of the alimentary canal, as for instance along with water or milk. Innumerable instances are on record in which direct and obvious excremental contamination of wells, springs, rivers and cisterns, has been followed by enteric-fever outbreaks. Perhaps one of the most remarkable

and extensive of this kind of epidemic was that which prevailed in 1890–91, in the lower Tees valley, caused primarily by the wholesale fouling of the river at Barnard Castle, at a spot above the intake of the drinking water supplied to the neighbouring districts of Stockton, Darlington and Middlesborough. Milk is another medium which has long been recognized as a means for the spread of enteric fever; the infection being sometimes traced to the use of polluted water for washing out the cans or diluting the milk, and in not a few cases to the milk being infected more or less directly by a person suffering from the disease. Just as there is supposed to be a bovine scarlet fever and diphtheria, so is it now believed by many that there is also a bovine enteric fever, the infection of which is communicated by the milk yielded by the affected cows to those who consume it. It is questionable whether the popular idea of mere sewer gases and emanations from drains can be regarded as direct causes of enteric fever; they undoubtedly predispose to ill-health, and in that way may indirectly influence its occurrence.

Some authorities have dwelt strongly upon the influence which pollution of the earth by animal matter has in originating enteric fever; and in connection with this have traced a connection between movements of the ground-water and the occurrence of enteric sickness and mortality. In places where the soil is porous, the ground-water high, and wells and cesspools both more or less adjacent, doubtless this connection between rise and fall of the subsoil water with fall and rise of enteric prevalence may hold good; but for the ordinary conditions of English life there is reason to doubt its applicability.

From this statement of the nature of the infection, cause and spread of enteric fever, it will be readily understood that the risks of infection from the enteric sick to others is greatest in small and crowded homes, where careful nursing, scrupulous cleanliness as to attendants' hands and soiled bedding or clothing cannot be secured. When such can be obtained, as in the large hospitals, the enteric sick can be treated side by side with other cases with apparently little risk to the latter; the chief precautions needed as preventive measures being disinfection of all clothing and articles which have been soiled by the sick, no matter how slightly, scrupulous cleanliness of the attendants' hands, and the exercise of the greatest care to disinfect all excretal discharges, and so dispose of them as not in any way to contaminate sources of water, milk, or food.

Cholera.—It is usual to speak of this disease as being endemic in that part of India known as Lower Bengal, because it is constantly present in that district, but there is reason to believe that

its endemic area is not, strictly speaking, limited only to that part of India, but that it is endemic in several countries of Central Asia. From these endemic areas cholera has at one time or other extended widely over the earth's surface, reaching on more than one occasion even these islands. The mortality from this disease is enormous: in 1866, which was the last occasion on which cholera was epidemic in England, the mortality was 672 per million of people; in 1892, when the disease was epidemic in Russia and Hamburg, the mortality was 45 per cent. of those attacked. Warmth of climate seems to favour the activity of the cholera poison, inasmuch as it usually attains its greatest prevalence during the months June, July, and August. Excessive wet or cold arrests the disease, but moderate rainfall seems to favour it. Although all races seem to be liable to attack, the negro race appear particularly to be so. It is now universally acknowledged that the infective agent of cholera is a micro-organism, called from its characteristic shape the comma bacillus; and that this exists in and is given off by the sick person in enormous numbers in the intestinal discharges which are so typical of this disease. In its mode of spread, cholera closely resembles enteric-fever and epidemic diarrhœa. In all these diseases, contact with the sick is comparatively free from danger, the infection being given off by the bowel, and contained in the stools or evacuations, and in clothing or water fouled by them. Practically in only a very few cases is the infection carried by the air, and then only a limited distance; the vast majority of cholera cases are due to infection following human intercourse—that is, where the cholera-sick man goes, there with him goes the cholera infection. How far he will be able to diffuse the disease around him to others "depends entirely upon the filth facilities which exist; these facilities being those for fouling the soil, water and air. It is a filth-sodden earth, an excrement-reeking atmosphere and sewage-tainted water which are the true causes of cholera." These conditions all exist largely in Asiatic towns and villages; and just so much as these same conditions exist among European communities will cholera proportionately prevail.

The influence which animal pollution of the soil exerts upon cholera causation and prevalence has been largely dwelt upon by Pettenkofer and others, who in some places have traced a direct relation between movements of the subsoil water in polluted soil areas. The essence of this idea is, that the soil having become, at some time or other, fouled by the discharges from the cholera sick, contains in itself the infective agent of the disease. Any fall in the ground-water leaves the soil above it moist and full of air; these circumstances, if combined with a certain degree

of soil warmth, are conditions favourable to the activity and vitality of the cholera organism, which eventually becomes dislodged from the soil by ascending air-currents. Any rise in the ground-water level would, of course, have a reverse or fixation effect upon the soil-contained micro-organism. It is difficult to readily understand any frequent occurrence of this train of events, still the origin of many outbreaks of cholera in which no history of imported infection can be traced, is only to be explained by some such diffusion of an unexhausted specific contamination of the soil in previous years. From what has been said, it will be seen that, especially in regard to its connection with soil conditions and emanations, cholera bears some resemblance to epidemic diarrhœa, and that, in both cases, in localities in which the diseases are endemic, the soil is so charged with the necessary infective organism that direct emanations from it disseminate the disease. This soil origin of cholera is probably true for outbreaks in the endemic Indian area, but not so for outbreaks in England and Europe, where contaminations of water supplies and the like constitute the chief and only means of dissemination.

The preventive measures to be adopted are isolation, disinfection of all clothing and excretal discharges, combined with the investigation and correction of all insanitary conditions which are conducive to outbreaks of the disease. A matter of considerable importance in this direction is the due appreciation of the fact that the infectivity of cholera evacuations lasts longer often than the existence of acute symptoms. The want of a proper recognition of this fact probably has been the cause of very considerable diffusion of infection in the past. The only safe precaution is to continue destroying by fire, or adequately disinfecting all bowel discharges for at least ten days after convalescence has commenced. This remark is equally applicable to both diarrhœa and enteric-fever as it is to cholera.

Simple Continued Fever.—A disease under this name is scheduled in the Infectious Diseases Notification Act of 1889 as one to be duly notified to the sanitary officials. It is doubtful whether any separate disease of this name really exists. The term is usually applied to cases of more or less transient fever, unattended by any definite and constant symptoms other than those commonly associated with a high body heat. Careful inquiry generally throws light upon the cause of these cases, a great number of them in reality being but mild and irregular examples of more serious diseases, such as enteric fever, typhus, or even measles; hence the great practical value of duly giving notice of their existence.

Yellow Fever.—This is a very infectious malady which

frequently prevails in the West Indies, Mexico, Brazil, and on the West Coast of Africa. Spain and Portugal are practically the only European countries ever affected with it, and even there it rarely spreads. It is essentially a disease of towns, particularly sea-coast towns where insanitary conditions of every kind abound. Outbreaks frequently occur on board ship, and are even there usually associated with similar filth conditions. The precise cause of the disease has not been discovered, but there is some evidence in favour of its being a soil-produced infection. Persons long resident in places where it prevails appear to have a remarkable immunity from yellow fever; new arrivals, on the other hand, are very readily affected. The infection tends to follow maritime traffic, and may be conveyed by air for short distances, but most frequently by means of clothing and goods. Its incubation period varies from one to five days; while its infectivity lasts some two to three weeks. There is at present no evidence that yellow fever is spread by infected water or milk, though probably in some cases it may be so diffused.

Relapsing Fever.—This is sometimes called "famine fever," and is very closely related to typhus fever. Climate and weather have no direct influence on this disease. Its chief causes are overcrowding and want of food. It is very infectious, being carried short distances by air and also by means of clothing. A peculiar wavy micro-organism, called a *spirillum*, has been found in the blood of the sick, and inoculation of the same has been found to reproduce the disease in men and monkeys. Relapsing fever appears to afford but little protection against subsequent attacks, but does seem to have some protective action against typhus.

Anthrax, or malignant pustule, is a very fatal disease, often given to man from animals, either by means of hair and wool, or from clothing. It is sometimes called woolsorters' disease, owing to its occasional prevalence among men employed in sorting various foreign wools. The infecting agents are the spores of a bacillus. To avoid the dangers attending the sorting of the more commonly infected wools, it is necessary and usual to wash and disinfect them, also to insist upon careful washing of the hands by all workmen before eating, and to change their clothes before going home. The actual sorting-rooms should be well ventilated, and artificial arrangements made for carrying away the dust while the bales are being opened.

Glanders, or farcy, is a rare disease in man, commonly communicated to him from the horse as a result of inoculation by means of the nasal discharges of the sick animal. It is very infectious, and has a short period of incubation of from three to six days.

Tetanus, or lockjaw, is essentially a soil- or earth-poison disease, due to the presence of a bacillus. It is not infectious, but commonly occurs as the result of the inoculation or fouling of wounds by dirt, mud or earth; this is the reason why it so frequently follows injuries to the hands and feet.

Rabies, or hydrophobia, has been already explained as being invariably caused by inoculation with the saliva of mad animals, mostly from bites by dogs, wolves, and even cats.

If, then, the foregoing is a true statement and explanation of the nature and causes of infectious diseases, what steps ought we, and can we take on their occurrence, to prevent their extension to others? Expressed briefly, the special and only precautions we can take to prevent the spread of infection are notification, isolation and disinfection.

Notification.—By this is meant the immediate intimation of the occurrence of every case of infectious disease to the medical officer of health. In the majority of places in this country, notification is by law compulsory on the part of the doctor attending the case, and by whoever is in charge of the patient; and on receipt of this intimation, the medical officer of health or sanitary officer has power to enforce such sanitary measures as may seem to him necessary. This law became necessary, and is likely to be necessary, because people, from a false sense of pride, are tempted to conceal the existence of infectious illness in their houses and families, with the result that the risk of spreading infection is not only greatly increased, but the chances of getting to know how and where it originated greatly impeded. If, on the other hand, one man or official is systematically informed of the existence of every infectious disease case, there is every chance of the cause of any outbreak being both discovered and removed, to say nothing of the greater security given to the community, that the health of the many will not be imperilled by the selfishness of the few. Under the Infectious Diseases Notification Act of 1889, the following diseases are scheduled: small-pox, cholera, diphtheria, membranous croup, erysipelas, typhus, scarlet fever, enteric fever, relapsing fever, continued fever, puerperal fever. Power is also given to the sanitary authorities, with the sanction of the Local Government Board, to include any other infectious disease, such as measles or whooping cough. Valuable as it is, notification alone can never stamp out infectious disease, because, as already explained, many cases are so mild that they run their course, and give off infection to others without their true nature ever being suspected. This is especially the case during epidemics of diphtheria, scarlet fever and small-pox, when persons suffer from sore throats, and attribute them to

cold, or have an eruption and think it to be chicken-pox, with the effect that, taking no precautions, they unknowingly give the disease to others. For this reason, notification alone is inadequate to check the spread of infectious disease; it must be supplemented by both isolation and disinfection.

Isolation.—This, to be of the slightest use, needs to be thorough, and means that, when infectious disease occurs in a house, the patient or sick person must be completely separated from the rest of the household. This can usually be satisfactorily carried out in most private houses, but is almost impossible in small shops, workrooms, business premises, schools, or the crowded dwellings of the poor. In these latter circumstances, the only alternative is to remove the sick person to a fever or isolation hospital, where he will no longer be the source of danger to others that he is in his own home. To relations and others, keen and anxious to nurse their own sick, the removal of them is often apparently hard and heartless, but a little reflection should convince them that it is equally heartless to expose others to the unsuspected risks of infection and death. On these grounds, the removal to isolation hospitals of the infectious sick, when so situated that their adequate isolation at home is impossible, is imperative in the interests of the community at large.

In all efforts to isolate a case of infectious disease in a private house, a room should be selected, if possible, on the topmost floor, and no other room be used on that level. The door of the room should, as far as practicable, be kept closed, or at least curtained off by means of a sheet kept saturated with some volatile disinfectant, such as a five-per-cent. solution of carbolic acid in water. The room itself should if practicable have a fire burning in it, and its windows kept open as much as possible. The room should be cleared of all unnecessary furniture, carpets taken away, hangings and curtains removed, and all stuffed or upholstered chairs replaced by plain wooden ones, such as can be readily cleaned. The passages and staircases leading to the infected room should be kept as airy as possible, by leaving windows open day and night, the idea being to so thoroughly dilute and ventilate the house that any chance escape of infection from the sick-room may be at once neutralized.

A special attendant or nurse should be detailed for the exclusive service of the sick person, and all general communication with the house reduced to an absolute minimum. Any articles brought to the room should be left at the door, or given to the nurse there, and no one allowed to enter except the nurse and the doctor. Those in attendance on the sick should not mix with the rest of the household, or, if this be unavoidable, the

sick attendants or nurses should invariably remove their dresses in the sick-room, wash their hands and face, and then put on fresh dresses, kept either outside or in an adjoining room; an alternative arrangement is to wear a cotton overall or wrapper, which can be laid aside when leaving the sick-room. All crockery, such as cups, plates, knives, forks, etc., necessary for the sick person and the nurse must be kept exclusively for their use, and on no account allowed to mix with others, or be passed into and washed in the kitchen. The cleaning of these articles should be performed by the nurse, and be done either in the sick-room, or just outside. The dress of the nurse should be of linen; woollen and heavy stuff fabrics are inadmissible. The clothes worn by the patient, and all bed-clothes should, as soon as removed from the person or bed, and, before being taken out of the room, be soaked in a disinfecting solution, such as four fluid ounces of izal mixed with 1 gallon of water, and afterwards in every case be boiled and washed quite separately from the other household linen. The same care needs to be observed in the treatment of all discharges from the sick person. Thus all discharges from the nose and mouth, which, in cases of diphtheria, scarlet fever and measles, are often both profuse and tenacious, should be wiped away with pieces of rag, which should at once be burnt; no handkerchiefs should be used; if they are, they must be burnt also. The bowel discharges so frequent in enteric fever, cholera, and diarrhœa should be received into bed-pans or utensils containing some disinfectant, such as corrosive sublimate solution (1 in 1000), carbolic acid (5 per cent.), or izal (5 per cent.); well stirred up, left for a quarter of an hour for the disinfectant to act, and either burnt, buried or discharged down the closet; if the latter is done, it should be well flushed afterwards. In scarlet fever and small-pox, when the infective matter exists in the skin particles so freely given off, care should be taken to render these particles innocuous. With a little care, this can to a large extent be accomplished by washing the skin with warm water and carbolic soap, and then smearing the body surface night and morning with a medicated oleaginous preparation made by mixing one drachm of carbolic acid and three of eucalyptus oil in eight fluid ounces of olive or almond oil. In the same diseases, much good results by syringing or swabbing out with pledgets of cotton wool the mouth and nose, with a warm solution of common salt (about two drachms of salt with half a drachm of boric acid to a pint of water), and then burning the wool after use.

As concerns the length of time isolation should be maintained, we may say that it should be commenced so soon as the case is suspected to be infectious, and continued until the doctor says

the sick person is safe to mix with others. It has already been explained that this period will vary. Thus enteric fever, diarrhœa, and cholera cases need to be isolated until the bowel discharges become natural; whooping-cough for quite two months; small-pox and scarlet fever until the skin ceases to give off branny scales or scabs—this is rarely in less time than six weeks; typhus, diphtheria and measles need isolation usually for a month; while mumps and chicken-pox for about two weeks.

Disinfection.—Allusion has already been made to the use of disinfectants in the management of infectious diseases, especially as an essential procedure to guard against their spread. Possibly with reference to no single matter concerning sickness and infection is there a greater amount of ignorance and misunderstanding among the public than on that of disinfection and disinfectants. The term "disinfection" means the destruction of the particular germ or micro-organism upon which any infection depends, and the expression "disinfectant" is applied to any substance which can so kill and destroy infection. Unfortunately, many people regard disinfection as meaning, not so much the killing and destroying of germs, as the removing, covering and destroying of unpleasant smells, or, at most, the arresting and impeding of putrefaction and the growth of microbes. While the first is carried out by a *disinfectant*, the second depends on the action of a *deodorant*, and the third upon what is termed an *antiseptic*. A substance which is a deodorant or antiseptic is not necessarily a disinfectant, neither is a disinfectant of necessity a deodorant. As a rule, of itself a bad smell does no harm, but it is of importance as indicating the existence and the presence of microbes; the mere smell can usually be disguised, removed, or hidden by such deodorants as eau de Cologne, camphor, sanitas, or even tobacco smoke; but these would all be useless as means of removing or destroying the germs which are the cause of the bad-smelling gases. Similarly, commencing putrefaction is checked by an antiseptic like Condy's fluid, but this fluid cannot kill and destroy the living infection matter or germs of disease, and is, in consequence, in no sense a disinfectant.

In actual practice, disinfection proper is largely aided by the preliminary removal of infection by the scraping and stripping of paper from walls, the washing and sweeping of floors, to say nothing of air perflation, and the washing, beating, shaking and exposure of clothes. These procedures, excellent in their way, are uncertain and incomplete; the destruction of germs, or true disinfection, is only attainable by either heat or chemical means. For articles of small value, the safest plan is to burn them, but when this cannot be done disinfection is best secured by exposing

them to either dry or moist heat. Experiments have shown that the highly resisting spores of bacilli are destroyed by an exposure for four hours to hot air at a temperature of 284° F., while steam at 212° F. killed them in five minutes. Everyday experience of disinfection shows that infection matter, to be destroyed, is rarely freely get-at-able or freely exposed, but lies enclosed in clothes, pillows, or beds, which are extremely bad conductors of heat. Unless raised to a heat which injures the fabric, hot dry air is unable to penetrate into the centre of non-conducting materials like blankets, beds, etc., and is in consequence unable to raise their deeper or central parts to sufficiently high a heat to destroy any germs lodged there. The prevalent idea of disinfecting articles of clothing by an exposure to dry heat in an oven is most mischievous and unsound, because, without the risk of injuring the materials or fabrics, no greater heat than 220° F. can be employed, and this temperature, unless maintained for something like eight to ten hours, is incapable of destroying infection. Hot air moistened with steam is somewhat better than hot dry air, but much inferior in both penetrating and germ-killing power to steam, especially steam which is superheated by being generated under pressure. In this form, steam rapidly penetrates into the interior of such articles as blankets, pillows and mattresses, raising the centre of them to a temperature of at least 212° F.

For disinfecting purposes, superheated steam under pressure requires to be applied in an oven specially constructed for the purposes; such an apparatus is Washington Lyon's disinfecting chamber, which in outward appearance is something like an ordinary steam boiler, but oval on section, and having a steam jacket all round the inner or disinfecting chamber. This chamber is fitted with a light frame on wheels, on which clothing, etc., can be suspended; it is run out of the door for this purpose. The frame being run in again, the door is closely and strongly fastened. Steam, at a pressure of 30 lbs. to the square inch, having a temperature of 273° F., is first turned into the outer jacket, so as to raise the temperature of the inner chamber to sufficiently great a heat as to prevent condensation of the steam when subsequently turned into it. At the ordinary pressure of the air, water boils at 212° F., and the moment the temperature falls below that heat steam condenses. At a pressure of two atmospheres, or 28 lbs. on the square inch, water boils at, and steam will not condense at, a lower temperature than 249° F.; while at a pressure of 44 lbs. to the square inch, or 30 lbs. above that of ordinary air, the boiling-point of water and condensing heat of steam is 273° F. If, therefore, the temperature of the inner chamber be kept at this heat by steam at this temperature being made to circulate around

it in an outer jacket, the steam when turned on into it will be kept constantly superheated, and will not condense into moisture unless the heat fall below that point. After the temperature of the inner chamber is sufficiently raised by the admission of steam to the outer jacket, the steam is then turned on into it, and kept on for some twenty minutes or so, or even longer, according to the nature and number of the articles within it needing disinfection. When this is done, the steam is cut off from the inner chamber and left on in the outer jacket only. The inner chamber thus becomes a drying cell, and any dampness which the articles, put in for disinfection, may have acquired thoroughly driven off before they are withdrawn.

There are some forms of steam disinfecting apparatus in which the steam is not under pressure, and in consequence of which the temperature does not exceed that of boiling water, or 212° F.; their disinfecting action is relatively weaker and slower than those in which the steam, being under pressure, is also superheated. The use of all or any of these processes cannot be undertaken in ordinary houses, but all health authorities now have them, and are prepared to remove, disinfect and return clothing, bedding, etc., free of charge. In sending articles for disinfection, by either dry or moist (steam) heat, it must not be forgotten that heat has a certain effect upon the colour and texture of fabrics exposed to it. Thus leather is shrivelled up and spoilt by steam, while hot dry air makes leather dry and brittle. Cotton and silk are not injured by steam at all, but, unless carefully regulated, are damaged by dry heat. Flannels, blankets, and woollen goods suffer little by either dry or moist heat, beyond some loss in colour; dyes appear to suffer little by either process.

The great drawback to the use of dry heat is the variation in temperature at different parts of the disinfecting chamber; and its effects upon fabrics vary according as to whether they are placed on the floor, or near the sides, or hung in the central or upper parts. With the use of steam, this variability of heat is not met with. As we have every reason to believe that infection—that is, disease germs—cannot resist a temperature of 220° F., or even 212° F., if completely and thoroughly exposed to it for some length of time, it seems unnecessary in most cases to carry the heat to excess. Practical experience goes to show that an exposure to 220° F. for 8 hours, or 250° F. for 1 hour, or 270° F. for a quarter of an hour is sufficient to disinfect ordinary infected materials. In the case of bedding, the hair or feathers in mattresses or pillows must always be taken out and loosened, before exposing them to disinfection by heat.

In circumstances where no means exist for disinfecting bulky articles of clothing and bedding by these methods, they should, if possible, be destroyed by burning; failing that, they should be boiled, or at least be allowed to soak for twenty-four hours in some disinfecting liquid, such as one of the following. (*a*) Izal 5 parts to 100 of water. (*b*) Chloride of lime 2 ozs. to 1 gallon of water. (*c*) Chloride of lime 70 grs. mixed with 6 grs. of herring brine to 1 gallon of water. (*d*) Carbolic acid 5 parts to 100 of water. (*e*) Bichloride of mercury $\frac{1}{2}$ oz., hydrochloric acid 1 oz., aniline blue 5 grs. to 3 gallons of water. Both these last two solutions are very poisonous, and, moreover, being powerful disinfectants, serve also excellently for adding to enteric or cholera discharges before passing them down closets or drains.

Many of the so-called disinfectants in common use are absolutely unreliable, particularly when unduly diluted. Large numbers of people appear to regard Condy's fluid as a disinfectant. It is merely a solution of the permanganate of soda or potash, which, as a powerful oxidizing agent, though capable of sweetening foul discharges from wounds, is nearly powerless to destroy the germs of infection. Clothes and bedding, therefore, which are merely dipped or soaked in it cannot be said to be disinfected. Chloride of zinc, in the form of Burnett's fluid, is much more powerful. It is well adapted for disinfecting cholera and enteric discharges, but is less so than either carbolic acid or the bichloride of mercury. Sulphate of iron or green copperas, if used in the strength of 1 lb. to a gallon of water, makes a valuable disinfectant for drains, but owing to its staining powers is unsuited for soaking linen or clothing. Sanitas, chloralum, eucalyptus, camphor, thymol, boric acid and iodoform, are not true disinfectants, or only so in the weakest manner. They are unfitted for the disinfection of fabrics and clothing.

Fumigation.—All attempts to disinfect clothing, bedding, etc., by mere fumigation at home should be discouraged, as it rarely succeeds in destroying the germs of infection. Fumigation of clothing can only be satisfactorily performed with sulphur, and then in a hot chamber such as Washington Lyon's or Ransome's, under the supervision of competent officials. Hair mattresses must be taken to pieces before fumigation. Far too great importance is attached by people to fumigation, and to the influence of chemical vapours as purifiers and means of disinfecting the air. The truth is, aerial disinfection is more or less of a delusion unless the air be rendered unfit to breathe. We should not aim at purifying old or fouled air, but rather renew it by free dilution and ventilation. It is, even in these days, no uncommon thing to see people placing saucers of

Condy's fluid or carbolic acid about sick rooms, or spraying the air with vinegar, terebene, eucalyptus and various other volatile agents, under the impression that they are disinfecting the air. All these efforts are in the main useless, and give a false sense of security, which at the same time diverts attention from more efficient measures. Much better hang up towels or sheets soaked in carbolic acid, of the strength of 1 part in 20 of water. Carbolic acid, being volatile, slowly diffuses and evaporates off the sheets, while the germs and dust floating about the air when they come in contact with the damp sheet stick to it. Another suitable way is to volatilize a disinfectant such as carbolic acid by boiling a table-spoonful of the strong acid in a kettle full of water, and allowing the steam which issues out of the spout to diffuse itself throughout the room. Of course any dust collected by sweeping infected rooms should be burnt at once.

It cannot be too clearly understood that while a room is occupied it is quite impossible to kill and destroy any infection or disease germs floating about in its contained atmosphere, without also killing those persons living in the room. But once the chamber is vacated we can, with some hope of success, endeavour to destroy all the infective microbes and their spores deposited in its dust on floors, ledges, or adhering to its walls and ceilings, by a combination of scrubbing, scraping, cleaning and the evolution of disinfecting gases. The principal gases used for this purpose are chlorine, sulphurous acid, and nitrous acid; they are respectively generated by the following chemical means :—

Chlorine is given off from chloride of lime when moistened with a little dilute sulphuric acid, and placed in a shallow vessel. A very useful formula for generating enough chlorine for 1000 cubic feet of space is to place in an open dish 8 ozs. of common salt and 2 ozs. of manganese dioxide, and then pour over them 2 ozs. of sulphuric acid and 2 ozs. of water previously mixed together, and place the dish in a pipkin of sand.

Sulphurous acid is most easily evolved by burning sulphur. The quantity burnt should be at least 3 lbs. for each 1000 cubic feet of space; it is better if 10 lbs. per 1000 feet be used. This gas has but weak germicidal powers.

Nitrous acid is readily evolved by putting a piece of copper into some nitric acid and a little water. For 1000 cubic feet of space, the quantities should be, copper shavings 1 oz., nitric acid 3 ozs., water 3 ozs.; the mixed acid and water to be poured upon the copper in a small jar.

The disinfection of the sick-room or other parts of a house after an infectious illness should not be neglected, as in no other

way can such infected buildings be made safe to live in again. A frequent and suitable way is as follows:—First remove all bedding, linen and clothing, and open all cupboards, drawers, boxes, etc. Next saturate the walls, floors and woodwork with water, and seal up all the openings leading out of the room such as the chimney, windows, cracks, doors, and ventilators by means of brown paper. Then set the disinfecting agent at work, whether chlorine, sulphurous or nitrous acids, as already explained, in the middle of the room. Go out quickly, shut the door, and paste up all the crevices round it, then leave the room in this condition for twenty-four hours.

On re-entering it, open all doors and windows, and strip the walls of the paper, burn the pieces, have the ceiling well lime-washed and scrub the floors, all woodwork and furniture, with the solution of corrosive sublimate given on p. 285. The reason for saturating the walls and woodwork with water before the fumigation is because these disinfecting gases act better in the presence of moisture. In many cases, where fumigation cannot be readily carried out, it will suffice to leave all doors and windows open for three days and nights, scrub all woodwork with hot water and soap, repaper the walls, and re-limewash.

From what has been said, it will be seen that so-called disinfectants and disinfection processes have not all the same value. The most powerful and reliable being fire, boiling, steam, exposure to dry air at or above 220° F. for from six to eight hours, corrosive sublimate (1 in 1000), and carbolic acid of not less strength than 5 per cent. The majority of the other reagents now in the market, and popularly regarded as disinfectants, are really not so at all, unless used in very concentrated solutions, but merely deodorants, or, at most, antiseptics or means of checking and delaying putrefaction.

CHAPTER VIII.

PARASITES.

In addition to the various micro-organisms referred to in the last chapter, and which it was explained are now regarded as the cause of the different infectious or specific diseases, the human body is liable to the attacks of various other organisms. These organisms are both vegetable and animal, and according to the nature and function of the respective parts of the body

which they attack, give rise to diseased conditions of varying severity. It is customary to speak of these living organisms, which are dependent upon or adventitious, as it were, to the human body as *parasites.*

The vegetable group of human parasites are almost exclusively met with on external parts of the body, and being of the nature of minute fungi, or moulds, they give rise to skin diseases of a more or less contagious character. Such are the various kinds of ringworm, chloasma and thrush.

Ringworm is the popular name for a large group of skin-diseases which have a certain family resemblance to each other, in that they often spread in the form of a ring or circle. All these diseases are produced by species of fungi, and, as a rule, have strong predilections for the scalp and other hairy parts of the body. Being intensely infectious or contagious, these vegetable parasitic diseases are readily transferred from one person to another. Ordinary ringworm is sometimes epidemic in schools, spreading from child to child by contact or contagion. The typical disease consists of circular patches varying from a six-pence to a five-shilling piece in size or larger, having a slightly raised or scurvy surface, the hairs on which are dry, brittle, lustreless and broken off close to the scalp. This condition is caused by the fungus attacking the hairs, a fact easily shown by soaking a diseased hair in weak potash solution, and then examining it under the microscope, when it will be seen that the hair is invaded to a greater or less degree by the fungus called the *Trichophyton tonsurans.* Ringworm of the body is marked by the occurrence of red, scaly, itchy and circular patches, and is excited by the same fungus as occasions ringworm of the scalp.

Favus, or scald-head, is another form of ringworm, caused by the fungus *Achorion Schönleinii*, and known by the presence of dry, light, cup-shaped crusts, out of which a hair sticks, and made up of fungus elements. Owing to the highly contagious nature of these skin diseases, care needs to be taken that they are recognized early, and treatment adopted. This consists in the killing of the parasite by means of repeated applications of iodine, or the use of germicides, such as corrosive sublimate. All infected hats, caps or clothing should be destroyed by burning.

Chloasma is a skin disease marked by fawn-coloured patches, occurring in the parts covered by flannel, especially the front of the chest and root of the neck. These are often raised and occasionally itchy. They are caused by the fungus *Microsporon furfur.* The liberal application of soap and water usually suffices to remove this parasite.

Thrush, or the greyish-white circular patches seen in the mouths of young and feeble children, especially when artificially or improperly fed, is due to a species of mould called *Oidium albicans*. This mould is probably identical with the oidium of milk, since the use of turned milk or a dirty feeding-bottle or tube by a child is almost invariably followed by the appearance of this parasitic growth inside the child's mouth. The occurrence of these patches indicates, not only that a child is not in the best of health, but also that greater care is needed to be observed as to the freshness of the milk or food and the cleanliness of the feeding-bottles. Every speck or patch of this oidium should be wiped out of the child's mouth, by either the finger or corner of the handkerchief, and the gums and insides of the cheeks washed over with either glycerine and borax, or with a solution of chlorate of potash.

The animal parasites which attack man are, for the most part, either insects which burrow into and attack the skin, or worms which infest the blood and internal organs. As will be seen subsequently, the most remarkable feature in animal parasites is the fact that their parasitism only represents a single phase in the life of the animal, and that while a few parasites, notably the parasitic insects, do not attain to sexual maturity until they have commenced to lead a free existence, the greater number of them, especially the worms, attain sexual maturity while in their parasitic stage, and therefore reproduce themselves in the body of their host.

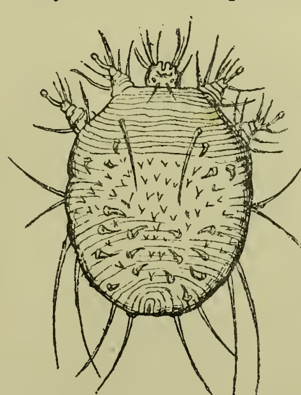


FIG. 68.—Acarus scabiei.

Scabies, or Itch, is caused by the burrowing into the skin of an insect called the *Acarus scabiei* (Fig. 68). This burrowing excites much itching and some rash. It is the female itch insect which thus burrows and causes the characteristic symptoms of this disease; for, burrowing beneath the cuticle, she lays her eggs at the end of the burrow, where they hatch, and the young insects then commence to burrow afresh in other directions. A very common place for itch to begin at is in the spaces between the fingers, and from out of the burrows, here or elsewhere, the acarus can be dug by a needle, if carefully looked for. The irritation which these insects set up is most intense, and often gives rise to

eruptions of pimples, blisters or pustules, which readily obscure the true nature of the affection. Owing to the ready means by which the itch insect can pass from one person to another, itch is eminently contagious, and the greatest care needs to be taken in separating those affected with the parasite from those who are free, and too, the most careful disinfection of all clothing which has been worn by the sufferer. For the actual cure of the itch, sulphur ointment is the best remedy, but needs to be supplemented by scrubbing the skin with soft soap and hot water. This scrubbing removes the loose scurf or scales of the skin, and helps the action of the sulphur by exposing the insect in its furrows.

The louse, or *pediculus*, may infest either the hair of the head or the body, in both of which parts it gives rise to characteristic irritation. Lice in the hair are quickly killed by saturating the hair with an ointment of corrosive sublimate; but a difficulty often exists in destroying their eggs or nits, which adhere to the hairs by means of a gummy matter. This can usually be dissolved by means of methylated spirits, and the nits detached by careful combing. The constant use of warm baths, soap, and scrupulous cleanliness are essential aids to keeping away the pediculi. The clothes of those affected with the body variety require exposure for some hours to dry heat of not less than 220° F., or else to be treated by one or other of the disinfection methods as detailed in the last chapter.

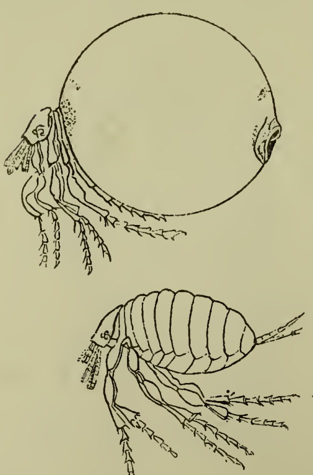


FIG. 69.—*Pulex penetrans*. Female and male.

Fleas and bugs are, in a sense, parasitic, but possibly less so than a special variety of flea met with in some parts of the tropics, called the chigoe, or *Pulex penetrans* (Fig. 69). These insects give rise to considerable pain and irritation, accompanied by swelling of the parts attacked. It is only the female insect which gives rise to these symptoms. While the male retains the ordinary form and habits of a flea, the female bores her way into the skin of the foot in man, dogs, and other animals, and becomes, by the enormous development of the ovary, a simple motionless bladder embedded in the flesh, around which, in course of

time, when the eggs have to be extruded, a certain amount of inflammation arises.

Guinea-worm, or the *Filaria medinensis*, is a formidable parasite, which, in some parts of Africa and India, gives rise to boil-like swellings and sores upon the ankles and legs. There has been much controversy as to how this worm gains entrance into man's system, some maintaining that the entrance is gained through the skin, either by a minute worm passing into a sweat-duct, or by a minute embryo coming in contact with a broken surface of skin; while others maintain that it always obtains entrance into the body by means of the drinking-water, and then works its way to the superficial parts at which it is generally found. At present this point is not definitely settled, but the opinion is gaining ground that the parasite enters the human body by means of drinking-water. The worm is about $\frac{1}{10}$ inch in diameter, and usually from 1 to 3 feet long. Like many other animal parasites, its presence in the tissues of man is but a portion of its life-history, and to complete its cycle of existence it requires to pass into the tissues of some other living organism. So far as is known at present, the history of this worm amounts to this. The worm having gained access to man's body in an embryonic state, requires some nine months for its development, and it is only when the stage of maturity is reached and the eggs are about to be hatched that symptoms, in the form of an abscess or boil-like swelling, appear which in anyway indicate its presence in the human tissues. The embryo which is emitted from man is aquatic in habit, and to further develop needs to pass into water. In this medium it meets with a fresh-water crustacean (*cyclops*), whose skin it quickly perforates, and in whose body it undergoes a certain degree of larval growth, and afterwards, with its host, the crustacean, reaches the inside of man, most probably by drinking-water. Its subsequent history in man is not known, but the inference is, that it burrows its way to the body surface in time to seek and secure an exit for its embryos into fresh water, in which medium they pass again through the changes already mentioned. This passing through one or more hosts, or individual living organisms, is characteristic of several other animal parasites of man, more particularly of the following, which mainly infest various parts of man's intestines or other viscera.

Filaria Sanguinis Hominis.—This is a minute hair-like worm, often reaching a length of three or four inches, found in the blood of men who have lived in certain tropical countries. It is considered to be the young form of another *filaria*-like worm, which, in the sexual state, is found in the lymphatics of the

subcutaneous connective tissue of persons suffering from two peculiar diseases called chyluria and elephantiasis. The former is marked by periodic attacks, in which the urine becomes milky and, upon standing, coagulates. This condition has been traced to an admixture of urine with lymph, and in which immature filariæ are visible under the microscope. Elephantiasis is attended by an enormous enlargement of the limbs and generative organs. The life-history of the *Filaria sanguinis hominis* is very curious. The parent worm, or that usually associated with chyluria and elephantiasis, and known as the *Filaria Bancrofti*, lies in a lymphatic, and here emits her young into the lymph stream, along which they pass through the thoracic duct into the blood. In the blood, these embryos or young are known as the *Filaria sanguinis hominis nocturna*, in consequence of their exhibiting there an extraordinary periodicity, abounding in the night time, but disappearing during the day, when they probably lie at rest in some abdominal or thoracic viscera. This periodicity is for some unknown reason an adaptation to the habits of the mosquito, which is the intermediate host of this parasite. The mosquito, as every one knows, is most active at night, and when it bites the human host, these filariæ curl round its proboscis and are then quickly transferred to its stomach. The greater number of the filariæ so swallowed by the mosquito are digested or destroyed, but a certain few undergo development inside its body, and, when the mosquito retires to some water to lay eggs, or to eventually die, these filariæ which have developed inside its body pass out by boring into the water, whence they get swallowed by man. Once inside the human stomach, the filariæ bore their way into the lymphatics, finally reaching their permanent abode in some distant lymph-vessel, where, as the *Filariæ Bancrofti*, they give rise to chyluria and elephantiasis, and breed, their progeny passing into the blood as before explained, till, released by the mosquito, they in their turn can complete their circle of development. Such being the history of this remarkable parasite, it follows that, to prevent people getting affected with it, all water in filaria districts should be boiled and filtered.

Dochmius Duodenalis.—This is a short worm, about half an inch long, which attaches itself, often in large numbers, to the villi of the small intestine. It is common in Egypt and some parts of Italy, where, on account of the large amount of blood which it abstracts, it produces a serious and fatal form of anæmia. The mature eggs of the worm, on being discharged from the patient's intestines, undergo their primary stage of development in wet soil, being much favoured by a high temperature. In the warm damp earth the parasite leads a free existence, and assumes a slightly

different shape to that which it presents when in the human bowel; instead of being rather short and stumpy, it is long and thin. From the soil to the well is but a short step, and, either in water—especially muddy water—or in earth adhering to food, this worm is transferred to the human alimentary canal.

Trichina Spiralis.—This is a small worm, varying from $\frac{1}{18}$ to $\frac{1}{8}$ inch in length, which not only attacks man, but also pigs and other animals, producing the disease known as trichinosis. In this disease the muscles present a number of ovoid cysts, about $\frac{1}{70}$ inch in length, just visible to the naked eye, within which is coiled an immature trichina, not much more than $\frac{1}{40}$ inch long (Fig. 70). If by chance the tissue or muscle containing the capsules be eaten, the capsule is dissolved, and the young worm set free; these rapidly develop, and breed so rapidly that within a week the embryos of the trichina, by burrowing through the walls of the intestine, are able to find their way into all parts of the consumer's body, especially the muscles, in which they soon get encapsuled, to go through the same history again. When trichinosis occurs in man, it is generally due to the eating of the imperfectly cooked flesh of pigs suffering from the disease. It is somewhat common in Germany, where sausages, hams and pork are more eaten than in this country. The symptoms of trichinosis are sickness, prostration, fever, and muscular pains. The mortality is often slight, but occasionally very high.

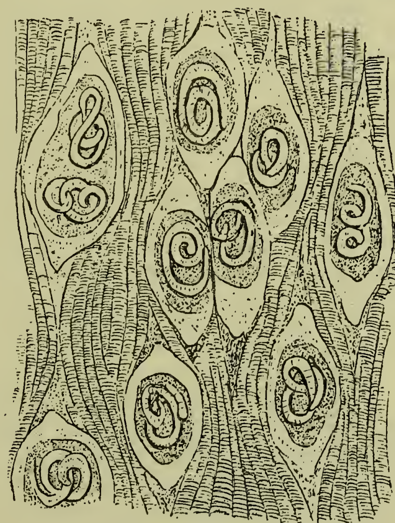


FIG. 70.—Muscle containing trichinæ.

Ascarides.—Under this name is included a large family of intestinal parasites. Of those affecting man there are three chief varieties; namely, the lumbricus or round worm, the thread worm, and a tropical kind called *Tricocephalus dispar*. The common round worm, or *Ascaris lumbricoides*, is very like an ordinary earth worm; it is pinkish in colour, tapering at each end, and some six inches long in the case of the males, and twelve inches in the case

of the females. In man, it usually infests the small intestine, where it gives off large numbers of eggs, which are oval, nodulated, and about $\frac{1}{450}$ inch in diameter. How and where the eggs develop is not known, but it is supposed to be in some intermediate host, possibly an aquatic host; it is chiefly through water that they appear to reach man. The thread worm, or *Oxyuris vermicularis*, is a well-known human parasite, occurring in large numbers in the rectum. The female is about $\frac{1}{2}$ inch long, and the male $\frac{1}{4}$ inch. This worm gives off enormous numbers of oval, unsymmetrical eggs, each being $\frac{1}{500}$ inch long, and about half as broad. Improperly cooked or raw vegetables and water are the vehicles by which they directly reach man from outside. The *Tricocephalus dispar* is possibly the most common of all intestinal parasites affecting man in the tropics. Its eggs are voided into the bowel, and when discharged from the bowel the embryo is not differentiated; its development remains in abeyance until the egg is carried into water or some damp medium. This happening, development proceeds, and on the egg being swallowed by man in his drinking-water, the embryo is liberated in the alimentary canal, and attaches itself to the mucous membrane of the cæcum.

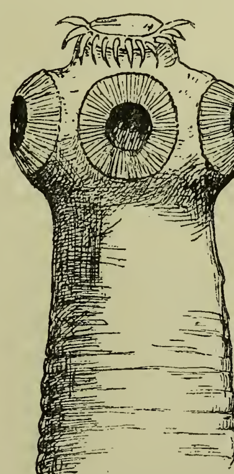
Bilharzia Hæmatobia.—This is another worm parasite, about $\frac{1}{4}$ inch long, which infests the veins of the large intestine, bladder and kidney, and gives rise to inflammation of these parts with the passing of blood in the urine. It is prevalent in Egypt, South Africa, and elsewhere. The urine usually contains the ova, or eggs, of the parasite, which are not more than $\frac{1}{180}$ inch in size, having, commonly, a sharp spine at one end. The bilharzia probably gains access to the human body through drinking-water, as we can follow the ova in their escape by way of the urine from the body of the primary host. In water, these ova hatch into minute ciliated embryos, which have been traced into the bodies of certain fresh-water arthropodes, which appear to play the part of intermediate hosts for them, in the same way as certain fresh-water crustaceans do for the embryos of the guinea-worm. If the water be drunk containing these arthropodes, the transference of these embryos of the bilharzia to man is as simple as it is certain.

Tapeworms.—These are a very common form of parasite in man, both at home and abroad; their life-histories are also peculiar, as they show that these parasites pass through two distinct phases in two different hosts. One phase of their existence is that in which the head, or *scolex* as it is called, of the parasite, together with a kind of bladder-like expansion, is embedded in muscle or other solid tissue. The bladder-like

12-15' in: in length

expansion or cyst is called a *cysticercus*. If the flesh containing these cysticerci is eaten by any other animal, the scolex or head reaches the intestine of its new host or the consumer, attaches itself to the wall of the intestine, and loses its cyst. Gradually, now from this head grow a series of segments, each of which is square or oblong, and each of which, too, is provided with double sexual organs. The segments are often called *proglottides*, and the chain or complete series of them may reach a length of many feet, the whole constituting the tapeworm. Each of the segments produces eggs or ova; these escape into the host's bowels, and are voided by him in his excreta. Some of the ova become attached to grass, or other vegetables, and with them are consumed by an herbivorous animal in whose interior the embryo develops from the egg, and quickly burrows into its host's solid tissues, where it changes into a cysticercus, to go through the same train of changes if devoured by a carnivorous animal. If not so devoured it remains passive, and eventually perishes.

Man is more subject to the tapeworm than to the cysticercus phase of the parasite's life. One of the most common tapeworms met with in man is the *tænia solium*, which often grows to a length of seven or more feet. Its head (Fig. 71) is about $\frac{1}{40}$ inch in diameter, and carries four suckers with a double circle of hooklets surrounding a prominence or *rostellum*. This tapeworm grows to its full size in about four months. The ova are spherical, $\frac{1}{700}$ inch in size. The cysticercus stage of the tænia solium is called the *Cysticercus cellulosæ*, and is most commonly met with in the pig, in which animal it constitutes the affection known as "measles," and measly pork is the chief source of *Tænia solium* in man.



Scolex

FIG. 71.—Head of *Tænia solium*.

Another tapeworm, somewhat like the preceding, only longer, is that called the *Tænia mediocanellata*. It is not uncommon in man. Its head is $\frac{1}{15}$ inch in diameter, resembles that of solium by having four suckers, but differs from it by not having either hooklets or rostellum. The eggs are oval, being about $\frac{1}{900}$ inch in diameter. Its cysticercus is called the *Cysticercus bovis*, because it occurs in the flesh of cattle; and the practice of eating underdone or raw beef is the chief source of the medio-canellata tapeworm in man.

A tapeworm which is very common in Russia, Poland, Sweden, and Switzerland is that known as the *Bothriocephalus latus*. It is a very long tapeworm, often reaching 30 feet in length. Its head (Fig. 72) is ovoid, $\frac{1}{10}$ inch long, and marked by two longitudinal furrows or suckers, but without hooklets. Its eggs are oval, about $\frac{1}{370}$ inch in size, and fitted with a lid at one end. Its embryo is a ciliated organism found in river water. Its cysticercus is supposed to be found only in fish, more particularly the pike.

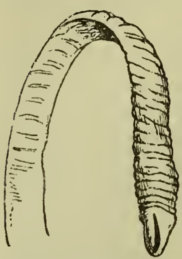


FIG. 72.—Head of *Bothriocephalus latus*.

Man is occasionally affected with a dangerous parasite under the name of *hydatid* disease. This commonly affects the liver, but may occur elsewhere. It is really the cysticercus stage of a tapeworm peculiar to the dog and wolf, and called the *Tænia echinococcus*. The head of this tapeworm is like that of the *Tænia solium*, only that it is but $\frac{1}{100}$ inch in width. The tapeworm is short, having, as a rule, but four segments, and the last segment only has reproductive organs. The echinococcus cysticercus in man, differs from all other similar cysts, in increasing indefinitely in size and forms, within itself, secondary cysts, some of which again enlarge, and form, by a process of budding, new cysts within themselves. Not only man, but many animals, are at times affected with hydatid disease, in whom the echinococcus cysts are often spoken of as "bladder worms." It is not difficult to understand how cattle become infected; for the proglottides and eggs of the echinococcus tapeworm, voided so constantly, and in such large numbers by the dog, readily find access on to straw, grass or even water, and with those articles of food and drink are consumed by the oxen. In the case of man, possibly the sequence of events is not much different. As with cattle, both proglottides and eggs of the tapeworm from the dog may in many ways be carried in food, especially uncooked vegetables, such as lettuces, or on the hands to the mouth, and thus reach the intestine. Probably, a greater risk of infection lies in the habit which dogs have of licking the hands and faces of their masters, and that often after they have been smelling and snuffing about other dogs. These are considerations which should prevent our too familiar association with dogs, more particularly to avoid their licking us, and frequenting dwelling-rooms or kitchens, to say nothing of keeping them clean, and that their excrement is not allowed to remain about. Moreover, full precautions should be taken to prevent infection of dogs by embryos of echinococcus, as may occur in slaughter-houses, where

the so-called bladder worms, or echinococcus cysts from slaughtered and infected animals are often carelessly thrown down. It is needless to say that dogs eating such echinococcus bladders would soon develop them into sexually mature echinococcus tapeworms. It is with a view to avoiding such possible contingencies as the foregoing that the model byelaws of the Local Government Board enact that "No dog may be kept in a slaughter-house; nor other animal, unless intended for slaughter upon the premises, and then only in proper lairs, and not longer than may be necessary for preparing it for slaughter by fasting, or otherwise."

Although the life-history of these various parasites is but imperfectly known, yet the remarkable facts, of which we have reliable knowledge, distinctly point to the great part which water plays in their diffusion to man, and the importance of avoiding all risks of infection by securing a good and pure water-supply; at the same time similar precautions are needed to see that all food is properly prepared and cooked before being eaten.

CHAPTER IX.

CLIMATE AND WEATHER.

OUR term climate is derived from the Greek word Κλίμα, a slope, and probably had its origin in the idea that the diversities of the qualities and conditions of our atmosphere varied according to the bending or sloping of the earth's surface from the equator to the poles.

The simplest plan of classifying climates is based upon geographical limits, and largely according to latitude. This at best is imperfect unless allowance be made for the influence of warm or cold sea currents, nearness or distance of mountain ranges, and large ocean areas. These latter in particular greatly affect rainfall and exposure to winds. Allowing for these modifying influences, and based upon the principle or limits of latitude, a commonly accepted classification of climates is as follows:—

Warm Climates.—These include what are called tropical and subtropical climates, marked by high temperature, heavy rainfall, and more or less well-defined dry and wet seasons. Such climates are usually met with in places lying between the equator and 35° of latitude north or south of it.

Though possibly all the diseases usually attributed to the

influence of warm climates are not rightly so, still they are peculiarly apt to be associated with such affections as heat-stroke, yellow fever, cholera, dengue, liver abscess, dysentery, small-pox and various forms of malarial fever, while scarlet fever and measles are comparatively rare.

Temperate Climates.—These have a mean temperature of 60° F., often with great extremes: four well-defined seasons, usually most rainy during autumn and winter, and the geographical limits of from 35° to 50° of latitude.

Cold Climates, or those belonging to regions situated between 50° of latitude and the poles. In them the summer is short, often lasting but a few weeks, while the winter is long. Snow is extensive, but of rain there is little or none.

The diseases of temperate climates are mainly those of every-day English life; while in the cold climates scurvy and scrofula are the principal affections which can be directly attributed to climate. The former arising from a deficient supply of fruit and vegetables, and the latter from the overcrowding and general poorness of living which prevails. Just as diseases of warm or hot climates have an affinity for the abdominal organs, so have the diseases of temperate and cold climates an affinity for the thoracic organs.

Mountain Climates.—These are peculiar, being marked by extremes of temperature, great clearness and rarefaction of the atmosphere, and lessened atmospheric pressure.

Mountain climates are peculiarly favourable to those having imperfect chest development, with hereditary or other tendencies to consumption; but are unsuitable for those troubled with chronic bronchitis or acute diseases of the lungs, kidneys, liver or brain. The peculiar effects of mountain climates appear to be due to the increased aeration of the blood which takes place during the act of breathing mountain air, and as a result of this, these climates are best suited for those capable of taking abundant exercise, and distinctly hurtful to the aged and very feeble.

Marine Climates are those prevailing upon islands, capes and sea coasts, in which the temperature is remarkably equal, rarely reaching extremes, and in which, owing to the increased moisture and rainfall, a certain softness of atmosphere is experienced. The climates of Great Britain, Norway and Iceland may be taken as types of these so-called marine climates.

The principal diseases which appear to be in any way peculiar to marine climates are rheumatism and the various affections of the lungs and air passages, the greater part of which may be due to the dampness and constant weather changes which are so characteristic of these climates.

The multitudinous effects which climates have upon health have long been recognized, and have constituted one of the most difficult questions which nations and governments have had to consider in regard to schemes of colonization, location of communities, and the movement of armies. So great is the influence of climatic conditions upon health, that it is probable that many of the divisions of the human race owe their principal and essential characters to its continuous action through successive generations. Note the difference between an Englishman and an Italian, or between a German and a native of India. These effects of climate appear really to be the expression or result of the influences of all the various elements or factors and conditions which go together to make a climate. Such are temperature and sunshine, rainfall and moisture, wind and atmospheric pressure or density. The systematic observation and study of these various phenomena constitute the science of meteorology.

Temperature.—One of the most remarkable facts in connection with man is that when in health he is able to maintain his normal or standard body heat of 98° to 99° F. under the most extreme and opposite climatic conditions. This, of course, is not always the case, for at times both extreme cold and heat profoundly affect man's physiological condition. Thus, prolonged exposure to extreme cold causes excessive contraction of the smaller bloodvessels, resulting in so great a shutting off of the blood supply to the extremities that they become gangrenous or frost-bitten. At the same time, if the exposure be very prolonged, the body loses all power of reaction, lassitude sets in, followed by deep sleep, usually ending in insensibility and death. More rarely the languid state is replaced by one of delirium not unlike intoxication.

Except perhaps in the tropics, the general effect of direct sun's rays on the body is beneficial; but prolonged exposure to great heat, whether in the sun or in the shade, is accompanied by pronounced physiological disturbance. Some experiments go to show that the body heat itself is increased $\frac{1}{20}$ degree for each degree (Fahrenheit) rise in the air's temperature, while the respirations of those living in hot countries, though at first (some six months) increased, are afterwards so much lessened in frequency that the entire respiratory function is reduced by about $18\frac{1}{2}$ per cent. Much of this lessened respiratory function in hot climates is said to be due to the fact that with a high temperature the quantity of oxygen present in the air is diminished. Thus, a cubic foot of dry air at 32° F. weighs 566·85 grs., which, neglecting the slight amount of carbon dioxide present, gives in that cubic foot of air 436·5 grs. of nitrogen and 130·35 grs. of oxygen.

Assuming that a man at rest breathes 16·6 cubic feet of air per hour into his lungs, he will at 32° F. receive 2164·2 grs. of oxygen per hour. At a temperature of 100° F. (which is not unusual in the tropics) a cubic foot of dry air weighs 498 grs., and is made up by weight of 383·5 grs. of nitrogen and 114·5 grs. of oxygen. Therefore in an hour, breathing as before, the man would receive 1901 grs. of oxygen, or nearly 12 per cent. less than he would breathe in at the lower temperature. The action of the skin is increased in hot countries by as much as 24 per cent., but the water exhaled by the breath and passed off by the kidneys is proportionately reduced. In hot climates, the general functions of the whole body become impaired, notably the nervous system and digestive organs, which, from being the seat of more or less increased action, are peculiarly liable to become congested and enlarged. The essential requirements for the bearing of great heat by the body is the maintenance of abundant perspiration; the moment this fails the heat equilibrium is disturbed, and the body heat rises rapidly, accompanied sooner or later by insensibility and death from heat-stroke.

Owing to our senses being insufficiently acute to measure slight changes in temperature, we have to make use, for this purpose, of instruments, called thermometers, which indicate, by means of the expansion or contraction of bodies under heat, its varying degrees of intensity. Liquids are the bodies best suited for this purpose in the construction of thermometers—the expansion of gases being too great, and that of solids too small. Of liquids, mercury and alcohol are practically the only ones used; the former because it boils only at an extremely high temperature, and freezes at a very low one, and the latter because at atmospheric pressure it does not solidify at the greatest known cold. For these reasons, mercury is used for recording high degrees of heat, and alcohol for low temperatures, the alcohol when so used being generally coloured. Although there are many varieties of thermometers, they can practically be divided into three kinds, namely, the ordinary, the registering, and the recording.

Ordinary thermometers consist of a capillary glass tube, at the end of which is blown a bulb or reservoir. The manufacture of a thermometer, to ensure accuracy, is one of great delicacy and care; in the first place the tube must be divided into parts of equal capacity, or *calibrated*, as it is called; next it must be filled and finally graduated for the construction of the scale. Just as a foot-rule is divided into a number of equal divisions called inches for comparison of length, so is a thermometer marked into a number of parts of equal capacity for the

comparison of temperatures, called degrees. Sometimes the scale is marked upon the thermometer stand, but in the best and more accurate ones it is marked on the actual stem.

Since ice constantly melts at the same temperature and distilled water under an atmospheric pressure of 29·92 inches and in a metal vessel always boils at the same temperature, these two temperatures are taken as the limits of the scale and the interval between them is taken as the unit for comparing temperatures, just as a foot or yard are taken for comparing lengths. The melting-point of ice or first fixed limit is usually called zero, and the other fixed limit the boiling point. On the continent of Europe, the scale of a thermometer is divided into 100 parts or so-called Centigrade. This division is really the simplest, and now generally used in this country in connection with all scientific work. In this scale, the zero or freezing point is at 0 degrees, while the boiling point is at 100 degrees. The degrees are usually designated by a small cypher placed a little above on the right of the number, thus 20°, while to indicate temperatures below zero, the minus sign is placed before, thus -10°, or ten degrees below freezing.

Another scale, known as Réaumur's, is used in Russia and some other parts of the Continent; in it the fixed points are the same as in the Centigrade: but the interval between them is divided into 80 instead of 100 parts; that is to say, 80 degrees Réaumur equal 100 degrees Centigrade, or 1 degree Réaumur is $\frac{5}{4}$ of a degree Centigrade, or 1 degree Centigrade is $\frac{4}{5}$ of a degree Réaumur. Consequently to correct Réaumur degrees into Centigrade ones it is necessary to multiply them by $\frac{5}{4}$. Similarly Centigrade degrees are converted into those of Réaumur by multiplying them by $\frac{4}{5}$.

In England and America, for general use, the thermometric scale invented by Fahrenheit is still employed. In this scale the higher fixed point is, like that in the Centigrade and Réaumur scales, that of boiling water; but the lower fixed point, or zero, is not the temperature of melting ice, but that obtained by mixing equal parts of snow and sal ammoniac, and the interval between the two is divided into 212 parts or degrees. The zero temperature on this scale is lower than that of melting ice, with the result that when a Fahrenheit scale thermometer is placed in melting ice, it stands at 32 degrees and, therefore, 100 degrees on the Centigrade scale and 80 on the Réaumur equal 212 less 32, or 180 degrees on the Fahrenheit, or 1 degree Fahrenheit equals $\frac{5}{9}$ of a degree Centigrade, and $\frac{4}{9}$ of a degree Réaumur. For the conversion of any given number of degrees Fahrenheit into Centigrade or Réaumur degrees, the number

32 must be first subtracted in order that the degrees may count for the same part of the scale, and the result then multiplied by the relative value of the two degrees. Conversely Centigrade and Réaumur degrees may be converted into Fahrenheit by adding 32 after multiplying by the ratio value. Thus, by the use of the following formulas—

$$\tfrac{9}{5}\text{ C.} + 32 = \text{F.} \qquad \tfrac{1}{4}\text{ R.} + 32 = \text{F.}$$
$$(\text{F.} - 32)\,\tfrac{5}{9} = \text{C.} \qquad (\text{F.} - 32)\,\tfrac{4}{9} = \text{R.}$$

we can show that $-20°$ F. equals $-6{\cdot}6°$ C., or $-5{\cdot}4°$ R., and that $20°$ C. equals $68°$ F., and $20°$ R. equals $74{\cdot}5°$ F.

A good mercury thermometer should answer to the following tests. When completely immersed in melting ice, the top of the mercury should exactly indicate zero or 32°, according as to whether the scale be Centigrade and Réaumur or Fahrenheit; and when suspended in the steam of water boiling in a metal vessel with the barometer at 29·92 inches, the mercury should be stationary at either 100° or 212° according to the kind of scale. The value of the degrees should be uniform, as shown by a detached piece of mercury occupying an equal number of degrees in all parts of the tube.

Owing to the temperature constantly varying, the actual reading observed has but a limited value, so that registering thermometers are required; of these there are two kinds in common use, namely, those known as minimum and maximum thermometers.

The minimum thermometer (Fig. 73), or instrument for registering the lowest temperature during a given period of time,

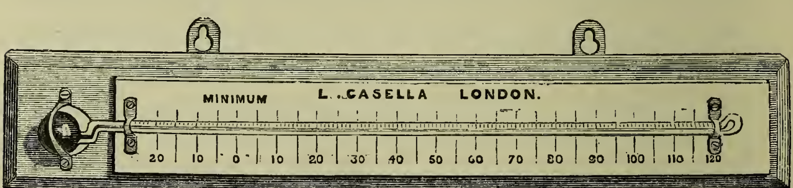


FIG. 73.—Ordinary minimum thermometer.

is sometimes known as Rutherford's minimum. In principle it is very simple, the bulb and part of the stem being filled with coloured alcohol in which a little glass or metal index is placed. When the temperature falls, and the alcohol contracts, the capillary attraction of the liquid draws the index back with it towards the bulb; but when the temperature rises again, the alcohol passes the index, and leaves the extremity of it farthest from the bulb at the lowest temperature reached. The instrument, after having

been read, is readily set by partially inverting it and letting the index fall to the top of the spirit column; it is then hung up in a horizontal position. Occasionally air bubbles appear in the alcohol and fix the index, while at other times some of the alcohol volatilizes and condenses at the top of the tube. Both these faults can be easily cured by holding the thermometer bulb downwards and swinging it rapidly round; this will usually cause the air bubbles to disperse, and displace any condensed alcohol from the top of the tube. If, by chance, as the result of this procedure, the index be thrown into the bulb, a little tapping and patience will bring it out again.

To avoid the annoyance arising from breakage of the column by bubbles of air, and from vaporization in alcohol minimum thermometers, Mr. Casella has invented a *mercurial* minimum thermometer (Fig. 74). In this instrument there is no steel or other index employed; its general form is shown in the figure, *c*

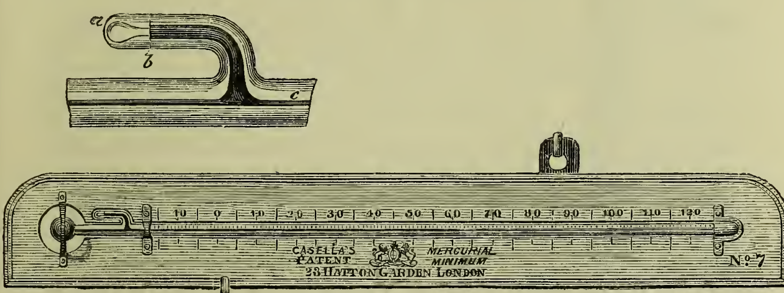


FIG. 74.—Mercurial minimum thermometer.

being a tube with large bore, at the upper end of which a flat glass diaphragm is formed by the abrupt junction of the small chamber *ab*, the inlet to which at *b* is larger than the bore of the indicating tube. The result of this is that, having set the thermometer, the contracting force of the mercury in cooling withdraws the fluid in the indicating stem only; whilst on its expanding with heat, the long or indicating column does not move, the increased bulk of mercury finding an easier passage through the larger bore into the small pear-shaped chamber attached. To set this instrument, it is necessary to raise or lower the bulb end, so as to cause the mercury to flow slowly, until the best part of the tube *c* is full and the chamber *ab* quite empty; if at any time mercury will not readily flow from the small chamber as above, a tap or jerk with the hand will cause it to do so.

Of maximum thermometers (Fig. 75), or those registering the highest degrees of heat during any given time, there are two in

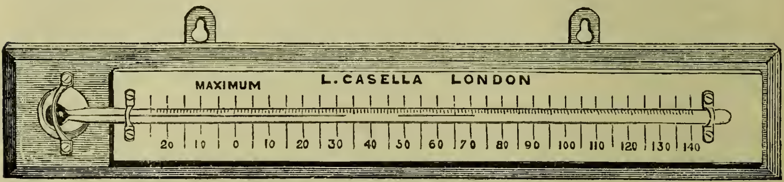


FIG. 75.—Maximum thermometer.

very general use, namely, Negretti's and Phillips's. Both these instruments have mercurial columns, a detached portion of which serves as an index for the highest temperature reached. In Negretti's, the detachment is made by means of a slight contraction of the tube, which, while allowing the expanding mercury to pass when the temperature is rising, is sufficient to overcome the natural cohesion of the metal, when contracting, to prevent it drawing it back on cooling. In Phillips's, the detached portion of the mercurial column is separated from the rest by a bubble of air. Both these instruments are placed horizontally, and both can be re-set by lowering the bulb, and then either gently tapping or swinging the thermometer.

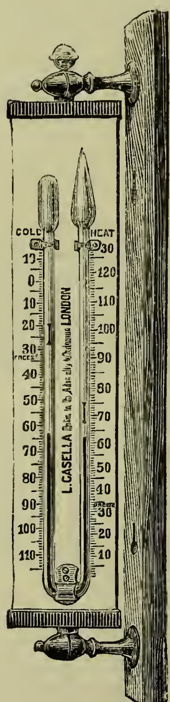


FIG. 76.—Six's thermometer.

Previous to the invention of these minimum and maximum thermometers, a registering instrument known as Six's thermometer (Fig. 76) from the name of its inventor, was much used, and is so now. The tube of the instrument is long and U-shaped. One limb constitutes the cold tube, and has at its extremity a bulb, while the other limb is the heat tube, having at its top or end a small chamber in which is confined some air. The middle portion of the tube contains mercury extending round the bend and part of the way up each limb. The bulb and both tubes or limbs above the mercury contain alcohol. Inside the alcohol are two steel indices, one being in the cold tube and the other in the heat tube. These are readily set, or caused to rest gently upon either column of mercury by moving them by means of a magnet. This being done, if the temperature rise, the alcohol in the bulb

will expand and push down the mercury in the cold leg, but raise that in the heat leg, and by so doing drive up the index in it until the temperature ceases to rise, when the point of maximum heat will be indicated by the lower end of that index. On a fall of temperature precisely the reverse will happen, for then the spirit within the bulb will contract, and the pressure in the air chamber at the top of the heat leg will force the mercury down in it, but up in the cold limb, while the cold index will continue to go up so long as the temperature continues to fall. Of course the scales read downwards on the cold leg and upwards in the heat one, and in each the lower end of the index shows respectively the lowest and highest temperature reached since the instrument was last set. The presence of the air chamber makes a Six's thermometer unsuited for travelling, and necessitates the vertical position.

Of recording thermometers, the cheapest are those of Cripp's or Richard. The bulb is a large curved flattened tube, filled with a liquid which tends to straighten with an increase of heat, and this being connected with a long lever in such a manner as to rise with increase of temperature and to fall with decrease, marks a tracing line upon a revolving cylinder. This cylinder depends upon a clockwork arrangement, and can be wound up, started and left untouched for given periods of time, at the end of which records of temperature will be found for every instant during the period. As the curvature of the tube and the spring mechanism are apt to alter, these instruments need to be corrected and compared periodically with an accurate mercurial thermometer.

In all efforts to compare climates or temperatures, it is not only necessary to have accurate thermometers, but also to place them so far as possible under similar conditions; for this purpose uniformity of exposure is obtained by placing or exposing thermometers in certain standard screens. The thermometers already described are invariably kept in the shade, and carefully protected from all direct rays of the sun and effects of reflected or radiated heat from walls and buildings. Owing to this fact, these instruments are sometimes spoken of as shade thermometers in contradistinction to others which will be described later on, and known as sun thermometers. The screen or arrangement for shade thermometers is a hut or box known as Stevenson's screen (Fig. 77). It is made of stout boards, with a ridge roof and louvred sides open below, and standing some 4 feet off the ground on four legs. It is placed where it will be freely exposed to the movements of the air, and at least 20 feet away from any house or building. All thermometers should be read once

daily, say 9 a.m., when the highest and lowest temperature of the previous twenty-four hours will be recorded.

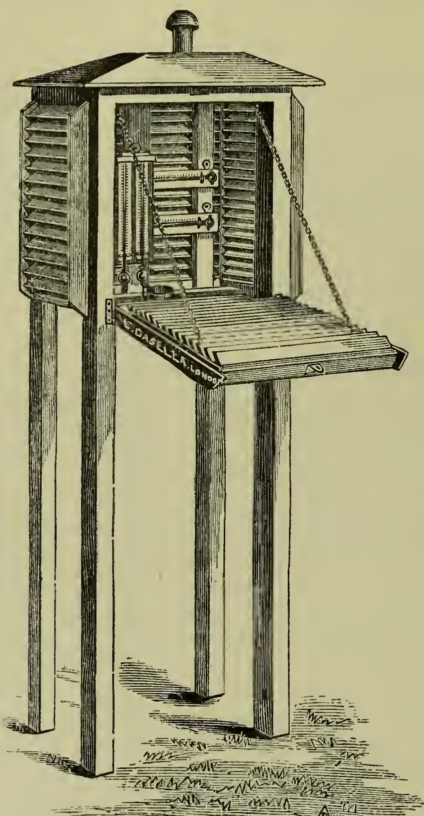


FIG. 77.—Stevenson's screen.

The mean temperature of the day may be obtained by taking a single reading at 9 p.m., or by taking the mean of two readings at 9 a.m. and 9 p.m., or by taking the mean of the maximum and minimum recorded temperatures; this is usually correct for winter, but in summer may be as much as 2° too high. A more accurate result may be obtained for the British Isles by employing the following method recommended by the late Rev. Dr. Lloyd. Multiply the difference between the observed maximum and minimum by the proper factor obtained from the following table, and add the product to the minimum.

Month.	Factor.
January and December	0·520
February and November	0·500
March and October	0·485
April and September	0·476
May and August	0·470
June and July	0·465

If observations be taken at 7 a.m., 2 p.m., and 9 p.m., or at t, t' and t'', the following formula by Herschell may be used, $\frac{t + t' + t''}{4}$ = mean temperature of day; if the hours are 8 a.m. 3 p.m., and 10 p.m., the formula is $\frac{7t + 7t' + 10t''}{24}$ = mean

temperature. The only true mean can be obtained by taking a mean of hourly readings. The weekly, monthly, and annual means are derived from daily means. As a rule, the lowest temperature is recorded at 3 a.m. and the highest at 2 p.m., but of course proximity to the sea or elevation and influence of latitude considerably affect these observations.

The investigations of M. de Candolle have shown that when the temperature of the air is above 42° F. the progress of vegetation is accelerated, hence it is of importance to agriculturists to know how much and for how long the temperature is above or below that heat. This is sometimes spoken of as the *accumulated* temperature, while the difference of 1° F. either way from the base temperature of 42° F. for 24 hours is called a "day degree." Thus an average warmth of 44° F. for 24 hours means two day degrees positive to the good for vegetation, and an average of 39° F. for the same period means three day degrees negative. Hence for each kind of crop, one can begin at seed-time, add all the positive day degrees, omit all the negative, and estimate the total or accumulated heat required to ripen the crop; or by collecting the day degrees to the good and to the bad, week by week, one can keep a kind of debit and credit account as the season advances.

Some idea of the intensity of the sun's heat is obtained by means of what are called *solar radiation thermometers* or maximum thermometers placed direct in the sun's rays. In order to avoid loss of heat by reflection from the bright glass surface of the bulb, this and one inch of the stem is coated with lamp-black, and this again, to protect it from being washed off by rain, is placed in a glass case out of which air has been pumped to make it a vacuum. Unfortunately, the presence of the outer glass covering largely interferes with the cooling influence of wind which materially affects the distribution of heat by the sun in Nature. Notwithstanding this theoretical defect, the blackened bulb maximum thermometer *in vacuo* is the best instrument we have for measuring the amount of heat given out or radiated by the sun. The instrument (Fig. 78) is exposed freely to the sun and air by fixing it horizontally 4 feet above the ground, well away from trees or walls, and with its bulb, in this country, pointing south-east. The heat recorded by such an instrument will be the temperature at which an equilibrium or balance is established between the heat produced by the direct rays of the sun on the bulb, and the cooling caused by radiation or loss of heat from the bulb to the glass jacket or covering; this latter, of course, will have practically the same temperature as that of the air. It follows, therefore, that the excess of the temperature of the black bulb over that of

the outer air, as registered by the maximum shade thermometer, will be an approximate measure of the power of the actual sun's rays, or, in other words, the power of the sun's radiation of heat. Thus, suppose the black bulb thermometer show a reading of 116° and the shade or air maximum be 76°. The difference between them of 40° will be the approximate measure of the sun's intensity. As an alternative method, it has been suggested to expose alongside of the black bulb *in vacuo* a similar thermometer also *in vacuo* only with its bulb bright, and to register the difference between the readings of the two instruments as the amount of solar radiation. It has been objected, with some reason, to both these methods, that the indications of the black bulb or sun maximum thermometer are not of much value, because in the first place the sun's rays do not necessarily have their greatest power at the hour of maximum air temperature, but much earlier, and that to obtain reliable results we should therefore subtract from the black bulb reading, not the maximum, but the actual air temperature at the moment the black bulb reaches its highest point. What is really wanted is a measure of the total heat received from the sun, not a record of its maximum intensity at any particular time.

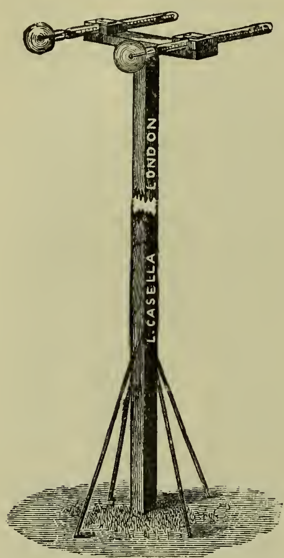


FIG. 78.—Solar radiation thermometer on stand.

Not only is there a constant gain of heat by the earth from the sun, but there is also a more or less constant loss of heat from the earth and from all objects on it. This loss of heat is spoken of as *terrestrial radiation*, and is very much greater when the sky is clear than when overcast with clouds, as, for instance, on bright nights. It is owing to the rapidity with which grass and vegetation radiates heat into space that grass plots and lawns are colder than bare flower-beds or gravel walks. This loss of heat from the earth is most marked where the disturbing influence of air currents is least. The amount of this loss of heat by radiation is determined by placing a minimum thermometer, as already described, on short supports some 4 inches off the ground on a plot of grass (Fig. 79). The difference or

defect of this minimum temperature below that of the air minimum in the shade is taken as the amount of terrestrial radiation.

Sunshine.—The duration of the sunshine is a very important factor in all climates, and the extent of this duration is recorded

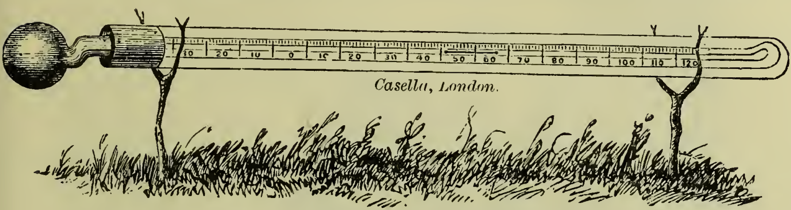


FIG. 79.—Minimum thermometer on grass for recording terrestrial radiation.

by either what is called Whipple-Casella's apparatus or by Jordan's. The former (Fig. 80) is mainly a glass sphere so mounted that when the sun shines its rays are focussed as by a lens upon a strip of cardboard, with the result that a burnt track or hole is left for such periods of time as the sun shines. The cardboard is so placed in the instrument that definite sections of it correspond to periods of time and hours.

Jordan's instrument is strictly speaking rather a recorder of sunlight than of sunshine. It consists of a circular box in which some sensitive photographic paper is placed, and the sunlight entering through a slit leaves a varying record of its duration and intensity. The paper can be readily "fixed" by washing in clean salt water.

Rainfall.—No factors have more influence upon the suitability or unsuitability of the climate of any particular country than the amounts of its humidity and rainfall. The latter is measured by what is called a rain-gauge, which, in its simplest form, is a copper funnel leading to a can or other receiving vessel (Fig. 81). In this country, the funnel is usually circular and eight inches in diameter, so that its area in square inches is accurately known. Having entered the funnel, the rain passes down a long and narrow tube which at its end is curled upward to check evaporation, into a metal collecting vessel. The rain having been collected in the receiver is measured in a graduated glass vessel, the divisions of which correspond to half-inches and tenths. The measuring vessel is divided proportionately to the area of the gauge, the diameter of which should always be some simple unit, like five or eight inches, so that if the original measure get broken, a new one can be readily improvised and graduated. Thus, take an 8-inch gauge, the diameter being 8 inches, its receiving area

is 50·26 square inches; therefore, one inch of rainfall, or rain one inch deep over a town, would deposit in that particular rain-gauge 50·26 cubic inches of water, or $29\frac{1}{2}$ fluid ozs. Therefore, if $14\frac{3}{4}$ fluid ozs. of water be poured into the proposed measuring glass, and the vessel be marked with a line at its level, that line

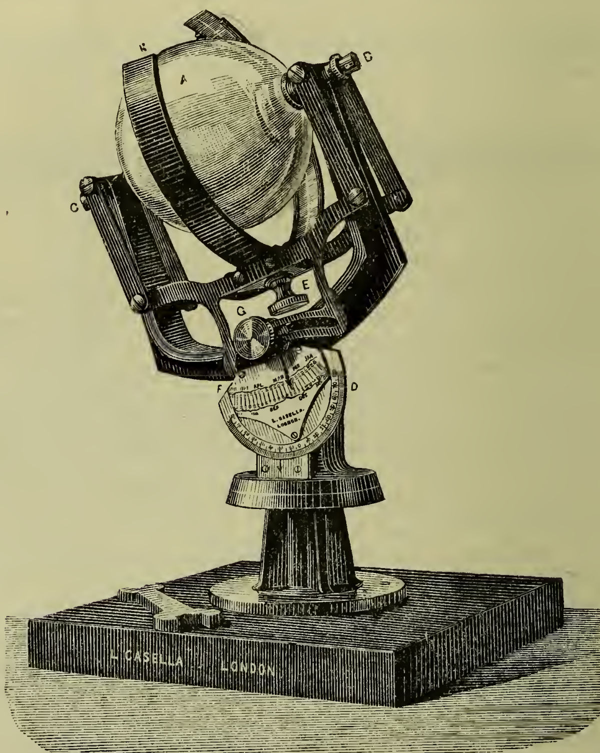


FIG. 80.—Whipple-Casella sunshine recorder.

will represent the graduation of half an inch of rain; subdivision markings are similarly made for tenth and hundredths of an inch.

The best place for a rain-gauge is on the ground in a well-exposed position, with the rim about one foot above the earth. A rain-gauge should never be placed upon a house roof, unless, as in towns, no sufficiently open space is available. The spot on which a rain-gauge is exposed should be clear of all objects whose height is greater than their distance from the gauge.

Rain should not be collected in the measuring glass, as it is liable to break, especially during frosts. Snow or hail can be measured by thawing the quantity collected and measuring the water which results. To avoid snow being blown out of the gauge, the upper edge of the funnel is usually fitted with a vertical rim about six inches in depth, and ground to a fine edge on the top.

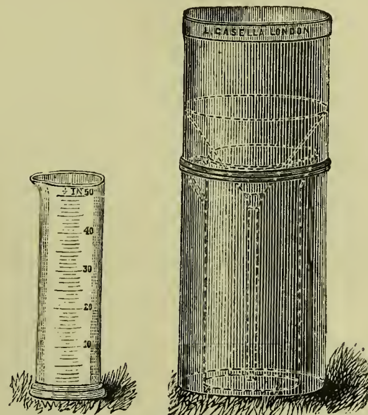


FIG. 81.—Rain-gauge and measuring glass.

The amount of rain which falls varies, of course, very much with the place; but in determining the average fall at any station, it is necessary to deal with observations extending over long periods. In England and Wales, the average rainfall each year is 33·76 inches; in Scotland 46·56 inches; in Ireland 38·54 inches. The average annual rainfall for the United Kingdom is 37·30 inches, for Great Britain 36·69 inches. On the east coast of England not much more than 20 inches of rain falls in a year, while on the west coasts of both Scotland and Ireland it averages as much as 60 or 80 inches; in some parts of Cumberland as much as 150 inches a year have been known to fall. It is very rarely that more than one inch of rain falls anywhere in Great Britain in one day; though occasionally as much as five inches have been known to fall. For furnishing meteorological returns, a minimum record of 0·01 inch is considered as characteristic of a rainy day in this country.

Humidity.—The question of the amount of moisture in the air is somewhat complicated, and is usually spoken of as the degree of humidity. It was explained in an earlier chapter that water is constantly evaporating into the air, and that the amount of water or moisture which the air can hold or retain is constantly varying with its temperature. Thus at 32° F. a cubic foot of dry air can only take up 2·13 grains of water, while at 100° F. it can take up as much as 19·84 grains. When air is so full of moisture that it can contain no more, it is said to be saturated. In this country the air upon an average contains about three-fourths of the amount of water needed to saturate it, that is, it has an humidity of about 75 per cent.; but if the air containing this amount of moisture be cooled down, it will reach

a degree of heat at which that same amount of moisture will suffice to saturate it, and if cooled still more it will reach a temperature insufficient to retain that moisture, with the result that it must part with some of it, the amount so parted with being precipitated or deposited as rain, snow, mist or dew. For instance, 100 cubic feet of air three parts saturated with moisture at a temperature of 70° F. would hold 600 grains of water; if for some cause or other the temperature of that 100 cubic feet of air were reduced to 61° F., that volume of air would become quite saturated, because at that temperature it could only hold 600 grs.; and if the temperature were still further reduced, say to 56° F., it could only retain 500 grs. of moisture; therefore the difference between 600 and 500 grs., or 100 grs. of water would be released or deposited as mist, dew, or rain.

It has been pointed out by some observers that occasionally, in perfectly pure air, a pressure of vapour may be maintained greater than that corresponding to the temperature of saturation (Aitken). In fact, that condensation will not in general begin unless some nucleus is present to which the particles of water can attach themselves. It is on the presence of solid particles of dust in the air that the formation of mists and fogs depends; the precise degree of mist or fog depending on the amount of dust present, and on the size and constitution of the particles. When the number of dust particles is large or their size considerable, and the quantity of vapour condensed is small, we get the phenomenon of a town, or so-called dry fog. The condensation of water upon invisible particles so increases their size as to make them visible. Often in the case of town fogs their obviousness is not so much due to the action of the moisture condensed on the particles as to the excessive size and quantity of the particles themselves. What are known as sea fogs, probably occur in air which is comparatively dry, because the dust in their case consists largely of salt grains derived from spray or surf, and which have a great affinity for moisture. If the quantity of condensed moisture is large, or the amount of dust and other solid nuclei small, we get what is called a mist, and it is merely a question of the degree of the moisture present which determines where the mist ends and actual rain begins.

The formation of dew is precisely analogous; in this case the solid substance on which the moisture is precipitated or condensed, is the surface of the ground, or a blade of grass, and not solid nuclei like soot or dust floating about in the air, as in the formation of fogs. Owing to the rapidity with which the earth, under certain circumstances, loses heat by radiation, as, for instance, on a fine clear night, the strata of moisture containing

air, in contact with the cooling earth, themselves become reduced so much in temperature that they are no longer able to retain their water vapour, but actually lose it by condensation upon the ground, where it constitutes what we call dew. The particular temperature at which air saturated or loaded with moisture deposits its water is called the *dew point*. It is from the determination of this dew point that the weight of water present in the air (or, in other words, the percentage of saturation of the air for the existing temperature) is calculated. This, of course, expresses the degree of humidity.

For the determination of the temperature of the dew point, certain instruments called *hygrometers* are used. Of these there have been many varieties. A very ingenious instrument of this kind is that known as Dine's hygrometer (Fig. 82). Some cold water is put into the cup A, and allowed to flow through the channel D, whence it rises through a perforated diaphragm into a space above, in which rests the bulb of a thermometer; the space itself being rendered water-tight by a thin cover of blackened glass, E. On turning the tap B, the water flows through the chamber, and so cools the glass cover down until a thin film of dew or moisture is deposited on it from the contiguous air; the precise temperature of this dew point, or moment of dew, being deposited on the black glass is read off on the thermometer C, and recorded as that of the dew point.

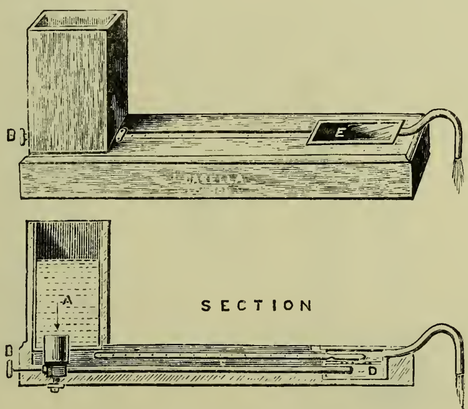


FIG. 82.—Dine's hygrometer.

Another instrument, known as Daniel's hygrometer (Fig. 83), consists of a bent tube with a globe at each end, and is partly filled with ether, the rest of the space in the tube being filled with the ether vapour, all the air having been expelled. One globe is made of blackened glass, and contains a thermometer, while the other is covered with muslin. Before using the instrument, the ether is made to pass into the blackened globe containing the thermometer, while the muslin surrounding the

second globe is moistened with ether. This ether rapidly evaporates, causing a condensation of some of the ether vapour inside the tube; this in its turn produces an evaporation of the ether in the blackened bulb. Now, whenever evaporation occurs, there is absorption of heat so that the black bulb gradually becomes colder and colder, and the moment is soon reached when the air in contact with it begins to deposit dew on its surface. So soon as this happens, the temperature shown by the contained thermometer is read off and recorded as the dew point.

The most common form of hygrometer now employed in this country is that known as the dry and wet bulb ther-

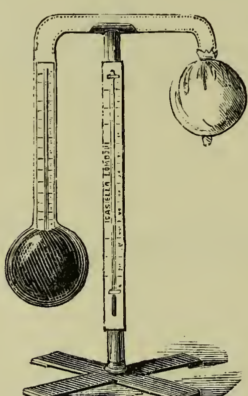


Fig. 83.—Daniel's hygrometer.

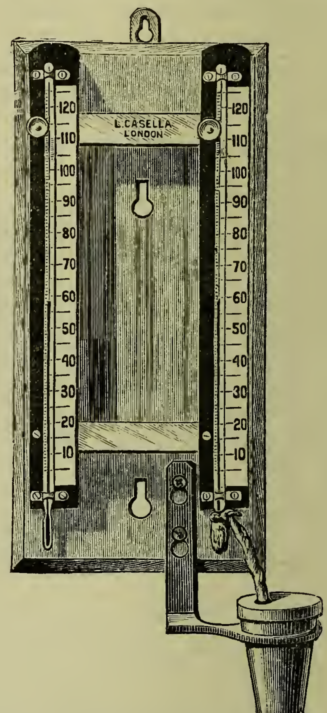


Fig. 84.—Mason's hygrometer, or the dry and wet bulb thermometer.

mometer (Fig. 84). It really consists of two ordinary thermometers mounted on a frame side by side. One of these has its bulb covered with muslin, and kept constantly moist by being connected with a small vessel containing distilled water, by means of the capillary action of a piece of cotton wick, which has been previously well freed from grease by being boiled in ether. The dry bulb gives, of course, the temperature of the air, while the wet one, in consequence of the evaporation constantly going on from its surface, gives a lower reading. The difference between the two temperatures recorded indicates the rapidity

with which evaporation is proceeding, and, moreover, since evaporation is faster the drier the air, the indication of the degree of evaporation is a measure of the dryness or moistness (otherwise humidity) of the air. If the air be saturated with moisture, of course no evaporation is going on, and the two thermometers will record the same temperature. In frosty weather, frequently the muslin covering and the water in the vessel will freeze, with the result that evaporation will not take place. In such case, it suffices to brush the frozen muslin over with a brush dipped in cold water and allow this to freeze, at such time evaporation will be going on from the ice surface so that it will be equivalent to its having a damp but unfrozen bulb.

The calculation of the dew point from the readings of the dry and wet bulbs can be roughly made by taking it to be as much below the wet bulb reading as that is itself below the dry; but for greater accuracy use must be made of certain factors which have been worked out by Mr. Glaisher, and given in the following table :—

Reading of the dry bulb Therm. F.	Factor.	Reading of the dry bulb Therm. F.	Factor.	Reading of the dry bulb Therm. F.	Factor.	Reading of the dry bulb Therm. F.	Factor.
10°	8·78	33°	3·01	56°	1·94	79°	1·69
11°	8·78	34°	2·77	57°	1·92	80°	1·68
12°	8·78	35°	2·60	58°	1·90	81°	1·68
13°	8·77	36°	2·50	59°	1·89	82°	1·67
14°	8·76	37°	2·42	60°	1·88	83°	1·67
15°	8·75	38°	2·36	61°	1·87	84°	1·66
16°	8·70	39°	2·32	62°	1·86	85°	1·65
17°	8·62	40°	2·29	63°	1·85	86°	1·65
18°	8·50	41°	2·26	64°	1·83	87°	1·64
19°	8·34	42°	2·23	65°	1·82	88°	1·64
20°	8·14	43°	2·20	66°	1·81	89°	1·63
21°	7·88	44°	2 18	67°	1·80	90°	1·63
22°	7·60	45°	2·16	68°	1·79	91°	1·62
23°	7·28	46°	2·14	69°	1·78	92°	1·62
24°	6·92	47°	2·12	70°	1·77	93°	1·61
25°	6·53	48°	2·10	71°	1·76	94°	1·60
26°	6·08	49°	2·08	72°	1·75	95°	1·60
27°	5·61	50°	2·06	73°	1·74	96°	1·59
28°	5·12	51°	2·04	74°	1·73	97°	1·59
29°	4·63	52°	2·02	75°	1·72	98°	1·58
30°	4·15	53°	2·00	76°	1·71	98°	1·58
31°	3·60	54°	1·98	77°	1·70	100°	1·57
32°	3·32	55°	1·96	78°	1·69		

To use the table, the rule is to multiply the difference between the readings of the two bulbs by the factor corresponding to the reading of the dry bulb, and subtract the product from the dry bulb; the result is the temperature of the dew point. Thus, say the dry bulb is 62°, and the wet bulb is 56°; their difference is 6, and this, multiplied by the factor 1·86, or that corresponding to the dry-bulb reading, gives 11·16, and this, taken from 62°, yields 50°·84 as the temperature of the dew point.

Having obtained the temperature of the dew point, the *relative humidity* is determined by further reference to a table, like the following, in which the weight of a cubic foot of vapour, constituting saturation, at various temperatures is given.

Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.
0°	0·55	26°	1·68	51°	4·24	76°	9·69
1°	0·57	27°	1·75	52°	4·39	77°	9·99
2°	0·59	28°	1·82	53°	4·55	78°	10·31
3°	0·62	29°	1·89	54°	4·71	79°	10·64
4°	0·65	30°	1·97	55°	4·87	80°	10·98
5°	0·68	31°	2·05	56°	5·04	81°	11·32
6°	0·71	32°	2·13	57°	5·21	82°	11·67
7°	0·74	33°	2·21	58°	5·39	83°	12·03
8°	0·77	34°	2·30	59°	5·58	84°	12·40
9°	0·80	35°	2·39	60°	5·77	85°	12·78
10°	0·84	36°	2·48	61°	5·97	86°	13·17
11°	0·88	37°	2·57	62°	6·17	87°	13·57
12°	0·92	38°	2·66	63°	6·38	88°	13·98
13°	0·96	39°	2·76	64°	6·59	89°	14·41
14°	1·00	40°	2·86	65°	6·81	90°	14·85
15°	1·04	41°	2·97	66°	7·04	91°	15·29
16°	1·09	42°	3·08	67°	7·27	92°	15·74
17°	1·14	43°	3·20	68°	7·51	93°	16·21
18°	1·19	44°	3·32	69°	7·76	94°	16·69
19°	1·24	45°	3·44	70°	8·01	95°	17·18
20°	1·30	46°	3·56	71°	8·27	96°	17·68
21°	1·36	47°	3·69	72°	8·54	97°	18·20
22°	1·42	48°	3·82	73°	8·82	98°	18·73
23°	1·48	49°	3·96	74°	9·10	99°	19·28
24°	1·54	50°	4·10	75°	9·39	100°	19·84
25°	1·61						

It is usual to express saturation by 100, and to calculate the relative humidity or the ratio of the absolute humidity to saturation by dividing the weight of a cubic foot of vapour corresponding to the temperature of the dew point by that corresponding to the temperature of the air, and multiplying by 100. Thus, taking

the same example as given above, in which the dry bulb reads 62°, the wet 56°, and the dew point is found to be 50°·84, and using the foregoing table, we get the weight of moist vapour per cubic foot corresponding to the dew point to be 4·21 grs., and this divided by 6·17, or the corresponding vapour weight for the air temperature, gives 0·68, and that multiplied by 100 shows the relative or percentage humidity to be 68.

This percentage saturation of the air is practically an inverse measure of the drying power of the air, and as such has a most important bearing upon climatic conditions, more particularly the degree of radiation from the earth's surface. We are all familiar with the peculiarly unpleasant effects of a hot moist atmosphere, and with the invigorating influence of dry and crisp air. A saturated atmosphere at from 35° to 50° F. will be found to be intolerably chilly, and although the evaporation may be checked, and this source of heat-loss removed, yet the conduction and radiation due to the vapour in the air will be enormous. A temperature of 50° to 65° F. in a nearly saturated atmosphere seems to be not uncomfortable, as under those conditions an equilibrium seems to be established between the cooling action by conduction and radiation, due to the vapour in the air, and the supply of heat from checked skin evaporation. A saturated atmosphere with a temperature of from 65° to 80° F. becomes oppressive and sultry. Above 80° F., a saturated air becomes most oppressive, and it is doubtful whether life could be long sustained in a saturated atmosphere of 90° to 100° F., as the surplus heat cannot be removed by conduction or radiation, while at the same time the natural effort of the system to produce evaporation is enormously exaggerated. Humidity of the air is very generally supposed to be associated with the spread, or rather prevalence of disease; much moisture in the air certainly favours the continuance of colds, but at the same time appears to relieve bronchitis by assisting expectoration and the general discharge of mucus. Malarial diseases are said never to attain their worst form except the air be saturated with moisture, but on this point the evidence is not very strong.

Evaporation.—How much water is returned to the atmosphere by evaporation from any moist surface, such as that of the earth, is a factor which largely affects climate, but our knowledge regarding it is small, as it is both complicated and regulated by the temperature, and the degree of moisture in the air and winds. In this country, the mean annual evaporation from a square inch of water surface has been calculated to be about 20 inches. Various attempts have been made from time to time to measure the evaporation going on. A rough idea of its amount can be

obtained by exposing a measured volume of water in an open vessel of known area, and deducting from its final volume, after exposure for a given period, the amount of rain which has been known to fall into it during that time.

Winds.—The facts relating to winds are practically limited to those connected with direction, force or pressure, and velocity. As a rule, there is comparatively little trouble in obtaining records as to direction, as if no vane is convenient, the smoke from a chimney will readily give the information, provided, of course, the

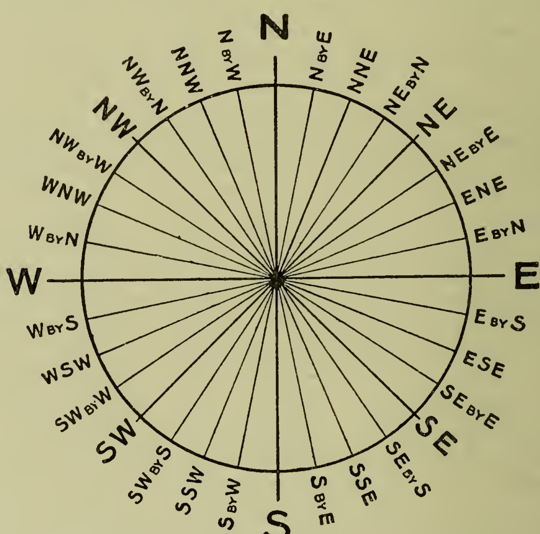


FIG. 85.—Points of the compass.

observer has a precise idea as to where lies his north or south. A wind vane should be placed perfectly clear of trees, buildings, or anything likely to deflect the course of the wind, and, too, should be kept clean, and oiled to avoid sticking. All wind observations should be recorded to the nearest point of the compass. To calculate the mean direction, it is usual to give an arbitrary numerical value to each observation, and then to analyze them. Thus, suppose we read to 16 points of the compass, and give a numerical value of 4 to each observation; if the wind be due N., we should give to N. the full value of 4; if the reading were N.W., we should give half the value of the observation, or 2 to N., and the other half to W. If the reading were N.N.W., then N. would get 3, and W. get 1, as their shares of the numerical value of the observation. Suppose we have the following observations of

wind direction recorded: S., S.E., E., S.S.E., N.W., W.N.W., N.E., E.N.E, N., N.E. The calculation of the mean direction is done in the following way. Giving to each observation a numerical value of 4, we get—

	N.	S.	E.	W.
S. =	—	4	—	—
S.E. =	—	2	2	—
E. =	—	—	4	—
S.S.E. =	—	3	1	—
N.W. =	2	—	—	2
W.N.W. =	1	—	—	3
N.E. =	2	—	2	—
E.N.E. =	1	—	3	—
N. =	4	—	—	—
N.E. =	2	—	2	—
	12	9	14	5

Then, deducting the opposite directions from each other, we get:—

N.	12	E.	14
S.	9	W.	5
Net N.	3	Net E.	9

That is, the mean direction lies in the N.E. quarter of the compass, and nearer E. than N. Since each quarter consists of 90°, the precise mean direction is at a point on the compass $\frac{3}{4}$ of 90° from N. in favour of E., or at an angle of $67\frac{1}{2}$° from N., which is a mean direction of E.N.E.

The instruments for the measurement of wind, either as regards its force or pressure and velocity are called *anemometers*. The earlier forms of these instruments were rectangular plates, whose movements, resisted by either springs or weights, recorded upon a chart by means of a connected pencil the amount of their displacement. In another form, the pressure of the wind is measured by making it blow into the mouth of an open tube kept facing the current by a vane, and noting the influence of the pressure exerted upon a column of water or mercury in a siphon. The later anemometers in use are those known as Robinson's (Fig. 86), consisting of four arms, each provided with a hollow cup and rotating horizontally on a vertical axis, which, by means of an endless screw, causes movements to be recorded upon a series of dials in terms of miles and parts of a mile. These instruments are graduated on the principle that, allowing for friction, the cups revolve three times slower than the wind moves; so that if the centres of the cups be 1·12 feet apart, each revolution corresponds to 3·52 feet of movement, or 10·56 feet of actual wind-motion, and that 500 rotations of the cups indicate 1 mile of wind. Owing, however, to the allowance for friction being placed probably too

high, and the cup motion being nearer 2 than 3 times slower than the wind, the velocity of wind movement as recorded by many instruments in general use is something like 20 per cent. too high. All anemometers to be reliable need to be kept scrupulously clean, well oiled, and placed in a thoroughly open position some twenty feet from the ground.

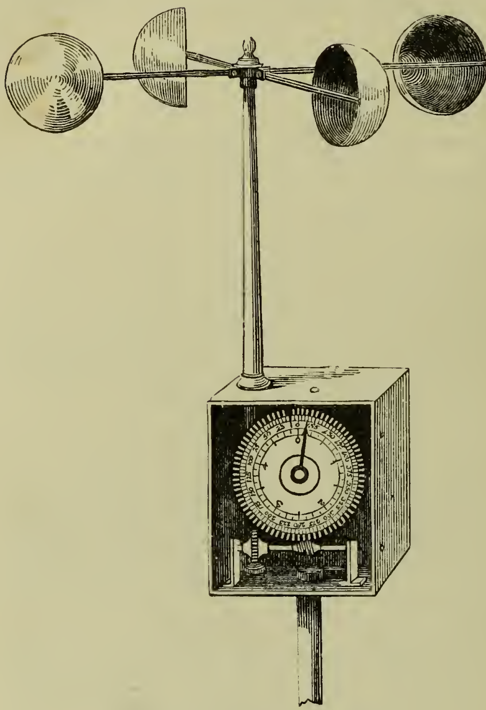


FIG. 86.—Robinson's anemometer.

Various proposals have been made for estimating and describing roughly the force of the wind. The earliest was that of Admiral Beaufort, who, in 1806, devised a scale having a relation to the pressure of the wind upon the sails of a ship, and the amount of canvas which she could carry. This is given in the following table, slightly modified, from Mr. Scott's instructions in the use of meteorological instruments:—

Beaufort Scale.	Description of Wind.	Velocity in miles per hour.
0	Calm	3
1	Light air	8
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

Attempts have been made to express the wind's force as a pressure of so many pounds to the square foot. From experiments with various kinds of anemometers, Dines calculates the pressure P of the wind in pounds per square foot from the recorded velocity in miles per hour, on the assumption that the pressure equals one two-hundredth ($\frac{1}{200}$) of the square of the velocity, or $P = 0{\cdot}005 \times V^2$. According to this formula, a wind blowing with a velocity of 50 miles an hour exercises a pressure of 12½ lbs. on the square foot.

In England, the wind has an average velocity of 8 miles an hour, and rarely exceeds 40. As a rule at midday the wind blows from sea to land, and from plains to hills, while in the evening the direction will be reversed. In this country, the most prevalent wind throughout the year is the S.W., the next is the W. The N.E. wind is the least prevalent, next the S.E., the E., and the N. The W. and S.W. winds are largely the result of the Gulf Stream, and are both warm and moist, while the E. and N.E. winds which blow from the cold areas of northern Europe and Asia are dry and cold. In all parts of the world there are periodical and variable winds due to local causes, while the permanent winds like the N.E. and S.E. trades take their direction from the rotation of the earth, and are caused by the constant movement of cold air from the poles towards the equator to replace the heated air of the tropics. These trade winds vary their prevalence over any particular area according to the season; but some other winds, such as the S.W. and N.E. monsoons of India, are essentially seasonal. The former is a wet wind, while the latter is in the main dry. The S.W. monsoon, usually commencing in May, is caused by the surface of the whole continent of India getting hotter than the sea, by which its air is rarefied, and rises to be replaced by comparatively cooler air currents laden with moisture blowing in from the Indian Ocean. The monsoon having exhausted itself by the time it reaches the northern limits of India, reverse currents of air begin to form, so that about October the wind blows southward from the N.E., and continues to do so until the same phenomena are started again in the early summer by the increased heat of the land. Among other seasonal winds may be mentioned the hot, dry Khamsan wind of Egypt which blows from the desert during the spring; while in the Mediterranean, the Bora and Mistral are two cold dry winds coming from some portion of the Alps, the one being a N.E. wind affecting chiefly the Adriatic, and the other a N.W. wind blowing powerfully over southern France. On the other hand, the E. or S.E. winds in the Mediterranean, commonly called the Sirocco, are hot, moist, relaxing, and proportionately unpleasant.

Clouds.—Although at present all efforts to estimate the amounts of cloud is unsatisfactory, still continuous efforts are being made to record their extent and conformations. As the outcome of an International Meteorological Conference, held at Munich in 1891, it is now usual to divide clouds into five large groups, namely: (A) clouds existing very high in the air; (B) clouds at a medium height; (C) clouds lying low or near the earth; (D) clouds in ascending currents of air; (E) masses of vapour changing in form. A cloud is nothing more than the condensation of vapour into visible shape, and may occur in either of two ways. Either a layer of the atmosphere is cooled in bulk to near its dew point, with the result that a stratified mass of cloud of greater or less extent is formed, as the so-called *stratus*, or a body of moist air is intruded into a mass which is cold and dry, resulting in a cloud of a heaped-up or *cumulus* form.

A close analysis of the various shapes or kinds of clouds has resulted in their being divided into four principal forms, namely, the stratus, the cumulus, the cirrus and the nimbus, while from these principal shapes result various modifications.

The *stratus* cloud can be best described as a widely extended but continuous horizontal sheet of vapour, very often forming at sunset.

The *cumulus* cloud is often very like a mountain in appearance, rising from a horizontal base; they are familiar to most people as conical heaps having often a bright or silver lining on the aspect towards the sun. The vapour in cumulus clouds is usually in the form of snow, and at its greatest density.

The *cirrus* cloud is best compared to a series of thin filaments not unlike a brush. It is the loftiest of all kinds of cloud, familiar examples being the so-called mares' tails, or parallel and diverging strips extending in any direction. Cirrus clouds are probably composed of ice or vapour in its least stage of density.

The *nimbus* is the true rain-cloud, being usually a horizontal sheet, having cumulus beneath and laterally, and with rain actually falling from it. Besides these four chief forms, there are compound modifications of them, the names of which are sufficiently descriptive. The following list will show the general distribution of clouds according to height; those marked with * usually accompany fine weather, while those with ** are characteristic of bad weather.

A. Usually lying at a height of 10,000 yards in the air.
 Cirrus.*
 Cirro-stratus.**
 Cirro-cumulus.

B. Commonly from 3000 to 6000 yards high in the air.
   Cirro-cumulus.*
   Cirro-stratus.**

C. Those having their bases from 1000 to 2000 yards high in the air.
   Strato-cumulus.*
   Nimbus.**

D. Those in ascending columns of air, their bases being as low as 1400 yards, and their summits from 3000 to 5000 yards in the air.
   Cumulus.*
   Cumulo-nimbus.**

E. Masses of vapour in transition shapes like fogbanks—up to 1500 yards.
   Stratus.

Atmospheric Pressure.—It has already been explained that the density or pressure which the atmosphere exerts is determined or noted by means of instruments called barometers. These are usually either mercurial, glycerine, water, or aneroid barometers. As commonly constructed, the mercurial barometer consists of a tube of glass about 36 inches long, closed at one end, filled with mercury, and placed vertically with the open end dipping into a cup containing mercury, called the cistern. When discussing the question of the weight of air, the principal of the construction of this instrument was explained, as also was the fact that the difference between the heights of the two mercurial surfaces exactly measured the atmospheric pressure. This in terms of mercury at sea level, in this country, is 29·92 inches. As the mercury in the tube balances, as it were, the pressure of the air, it is obvious that it falls with a lessened pressure, but rises with an increased pressure, so that if by means of a fixed scale we note the precise length of the mercury column, we may measure the weight of the atmosphere. Such a scale is commonly divided into inches or other measures of length. In some common forms of barometer, this scale is laid off from a zero at some fixed point in the cistern, with the result that, except at one particular point, the instrument reads wrongly, because during the changes which take place in the length of the column, the level of the mercury in the cistern also changes, being sometimes higher, and sometimes lower than the fixed zero point. In order to overcome this difficulty and source of error, various expedients have been resorted to, so as to compensate for the ever-changing level of the mercury in the cistern; thus, (1) by a so-called capacity correction which, duly noted and recorded on the scale by the maker, states the ratio of the interior area of the tube

to that of the cistern, thus capacity $\frac{1}{40}$. To apply this correction, there is always marked on the scale a certain height of the column which is correctly measured by the scale. This exact height is termed the *neutral point;* when the mercury sinks below this, the height read off will of course be too great, because the level of the mercury in the cistern will have risen above the zero in a proportionate amount; for the same reason, when the mercury rises above the neutral point, the reading will be too small because the level of the mercury in the cistern will have fallen below the zero of the scale. The capacity correction is applied by taking the indicated fractional part of the difference between the height read off and that of the neutral point, and adding or subtracting it from the reading, as the case may be. Thus, suppose in the case of a barometer marked with a neutral point, and with a capacity correction of $\frac{1}{50}$, the mercury stands one inch above the neutral point, then $\frac{1}{50}$ of the difference the height read off and the neutral point, or, in this case, one-fiftieth or 0·02 inch, must be added to the observed reading. (2) In the Kew barometers, the error is obviated by graduating the scale in nominal inches, which are shorter than true inches, from above downwards in proportion to the relative size of the diameter of the tube and cistern. (3) Another device is to do away with the cistern altogether, and employ a U-shaped tube, in which one arm is shorter than another, and open at one end. Both levels are read upon a scale, and the reading of the barometer is the difference in level of the mercury in the two legs. These are sometimes called syphon barometers, of which the ordinary wheel barometer is a common type; in this latter instrument the movements of the mercury are transmitted from a float on the mercury in the open tube, by means of a string, to an axis which carries an index moving over a dial-plate as in a clock. (4) In what are called the Fortin barometers, or best standard barometers, the necessity for capacity correction, or either of the other above-named devices is avoided by giving the cistern a pliable base of leather, and capable of being raised or lowered by means of a screw *c* (Fig. 87). The upper part of the cistern is made of glass, through which the zero of the scale can be seen as a piece of ivory, whose lower extremity is called the

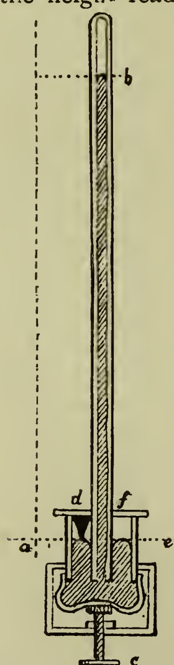


FIG. 87. — Diagram showing cistern of a Fortin's barometer.

fiducial point, *d*. Before taking a reading, the level of the mercury in the cistern must be set exactly to this point, by raising or lowering the cistern base by means of the screw; since the fiducial point is the tip of the piece of ivory, and accurately corresponds, as a fixed point, to the zero of the scale, after the level of the mercury in the cistern has once been carefully adjusted to it, it is obvious that the height of the column of mercury then read will be an accurate measure of the atmospheric pressure.

In order to secure greater exactness in the reading of a barometer, use is made of a secondary scale, or vernier, which slides upon the principal scale. In all standard barometers this vernier scale is so graduated that 25 of its divisions correspond to 24 of those upon the other, or fixed scale. Consequently, each space or division on the scale is $\frac{1}{25}$ of its own size larger than each space on the vernier, and as each such space on the scale is one-twentieth, or five-hundredths of an inch, therefore the vernier exhibits differences of $\frac{1}{25}$ of $\frac{1}{20}$ inch, or $\frac{1}{500}$, or 0·002 inch. In taking a reading of a barometer, the first thing to do is to note the temperature of the instrument by means of the usually attached thermometer; next, adjust the mercury in the cistern to the fiducial point, if it be one made on Fortin's principle; then place the vernier so that its lowest edge is level with the top of the mercurial column. If this level coincide exactly with one of the principal scale-divisions there is no need to use the vernier; but if it do not so coincide, the use of the vernier will accurately measure the excess of the mercury-level over the next lowest division or mark on the scale. To do this, we must follow the vernier scale up, until we find one of its marks exactly corresponds with one on the fixed scale; call it x, and, as each of these represents $\frac{1}{500}$, or 0·002 inch, we have $x \times$ 0·002 inch as the exact distance which the mercury column is over and above the next lowest mark to it on the principal scale. Thus, in Fig. 88, presuming that the lower edge of the vernier, A B, has been accurately adjusted to the level of the top of the mercurial column, we find that that corresponds to a point just below 29·20 inches, and something above 29·15 inches; that is to say,

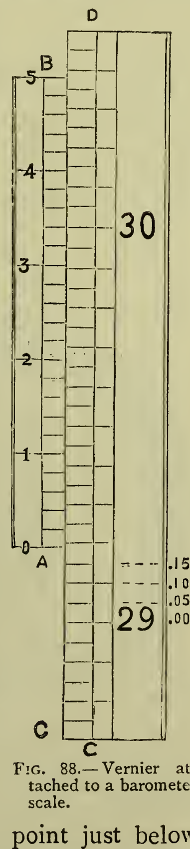


FIG. 88.—Vernier attached to a barometer scale.

neither of those readings give the absolutely correct height of the mercury. Following up the vernier, we find that its seventeenth line or mark is the first to exactly coincide with one on the principal scale C D; therefore, if we read that as meaning seventeen five-hundredths of an inch, or 0·034 inch, or the exact amount by which the top of the mercury column exceeds 29·15 on the fixed scale, we get by the addition of these two numbers 29·184 inches, as the correct reading of this particular example.

The reading having been thus accurately taken, it remains to apply certain corrections; these are (1) index error, (2) for capillarity, (3) for temperature, (4) for height above sea-level. The first two corrections have to do with the actual instrument, and are usually very small and determined before the instrument is sent out, and their amounts duly entered on the certificate which accompanies the barometer. The error due to temperature is one which affects, not only the mercury, but also the brass of the scale, and in extremes of heat or cold may be considerable; this explains why it is so important to note the temperature before taking the reading. To secure uniformity of barometric records all nations have agreed to reduce their barometer readings to what they would have been had both the mercury and brass scale been at 32° F., or 0° C. All good barometers are made with brass scales, and for these the necessary temperature corrections are given in the following table.

Temp.	27 inches.	28 inches.	29 inches.	30 inches.	31 inches.
30°	– 0·004	– 0·004	– 0·004	– 0·004	– 0·004
40°	– 0·028	– 0·029	– 0·030	– 0·031	– 0·032
50°	– 0·052	– 0·054	– 0·056	– 0·058	– 0·060
60°	– 0·076	– 0·079	– 0·082	– 0·085	– 0·087
70°	– 0·100	– 0·104	– 0·108	– 0·111	– 0·115
80°	– 0·124	– 0·129	– 0·133	– 0·138	– 0·143
90°	– 0·148	– 0·153	– 0·159	– 0·164	– 0·170
100°	– 0·172	– 0·178	– 0·184	– 0·191	– 0·197

Corrections for height above sea-level are usually made by reducing all readings to sea-level, which is the level of the mean half-tide at Liverpool. If we know the exact height of the particular spot above or below sea-level, the necessary correction is commonly obtained from specially prepared tables; but the application of this correction is very little needed in everyday life, unless records are made for scientific purposes. As an approximate calculation the correction may be said to be about 1 inch for every 1000 feet.

Although in the majority of barometers the atmospheric pressure is measured by a column of mercury because of its high specific gravity, still, in some others, other liquids are employed, such as glycerine, which, having a lower specific gravity, is much more sensitive to variations in pressure. The specific gravity or density of mercury is 13·59, while that of glycerine is but 1·26; the atmosphere we know can support a mercurial column 29·92 inches high; therefore, it can equally support a glycerine column 27 feet high: or, in other words, a fall of 1 inch in a mercurial column is the equivalent of a fall of 10·7 inches in a glycerine instrument—the latter, in consequence of its greater range, being far more sensitive as an indicator. Water barometers have also been made, in which the column required to balance the atmosphere is 34 feet. Besides mercurial, glycerine, and water barometers, familiar instruments in general use are aneroid barometers—their principle is very simple. They are small, air-tight metallic boxes, exhausted of air inside, but filled with peroxide of hydrogen, and so constructed that as the atmospheric pressure rises so the metal box is forced in, and, helped by means of a strong spring, bulges out again when the pressure lessens. The movements of the metal are, by a suitable arrangement of levers, made to turn an index on a dial face (Fig. 89). The dial is of course graduated, by comparison with a standard mercurial instrument. Aneroids are very sensitive and convenient, but liable at times to go hopelessly wrong, on which account they need to be periodically checked against a standard mercurial instrument. Mercurial barometers may be said to measure absolute pressure, while aneroids measure relative pressure.

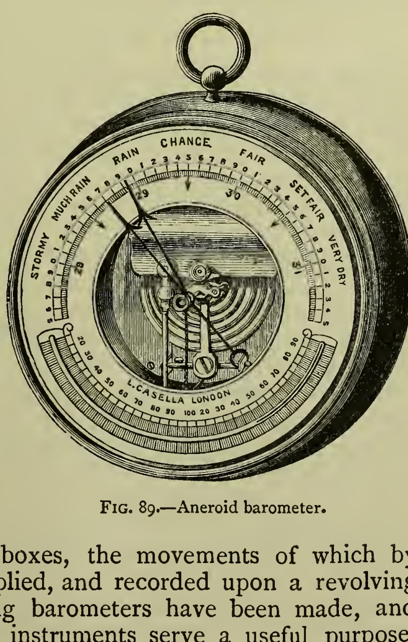


Fig. 89.—Aneroid barometer.

By a combination of a series of aneroid vacuum boxes, the movements of which by means of a lever are multiplied, and recorded upon a revolving cylinder, so-called recording barometers have been made, and for observatory work these instruments serve a useful purpose,

but, of course, are not absolutely accurate without being constantly checked against standard mercurial instruments.

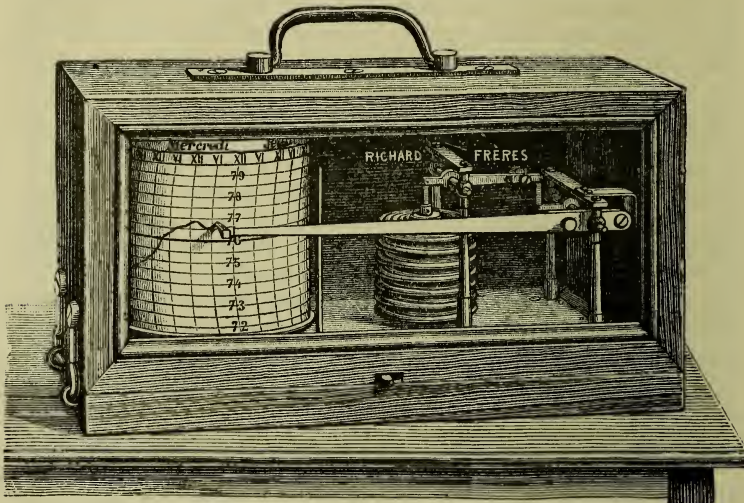


FIG. 90.—Self-recording aneroid barometer.

Barometers generally, and aneroids in particular, have been of the greatest value as measurers of the height of any given place above the sea-level; the barometer, of course, falls when heights are ascended, but the diminution of pressure is not uniform. Strictly speaking, such observations involve calculations of more or less complexity, but, for rough work, fairly accurate results can be obtained by simple rules. It is, however, necessary to make three readings of the barometer. Suppose it is required to know how much higher a town, A, is above a source of good water-supply situated at B. Read the barometer at A, go then to B and read it there, then back to A and read it there again; take a mean of the two readings at A, and determine the difference between it and the reading at B; this, multiplied by 9, and neglecting decimals, will give the difference in height between the two places in feet. Thus, suppose the first reading at A had been 29·94, and the second had been 29·90, the mean, of course, would be 29·92; and suppose the reading at B to have been 30·35, the difference between these two is 0·43, which, multiplied by 9 and ignoring decimals, gives 387 feet as the height of A above B. When the barometer at the higher station is below 26 inches, or the temperature above 70° F., the multiplying factor should be 10. The results by this method are fairly accurate.

In most parts of the world there are distinct periodical and non-periodical changes in the atmospheric pressure as indicated by the barometer, but in these islands the former are barely noticeable owing to the intensity of the non-periodical changes. In reality the periodic changes are in the form of two maxima, namely, at about 9 a.m. and 9 p.m., with two minima at 3 a.m and 3 p.m. In this part of the world the range between these two is not more than 0·02 inch, but in the tropics it amounts to quite 0·1 inch. The annual variation of pressure in this country is most variable, but the maximum readings are usually about the end of May or early in June, while the minima are at the end of October or early in November.

Unless very extreme, variations in atmospheric pressure appear to have only an indirect influence upon health; but when the barometric pressure is lessened to the extent of some inches, as in mountain climbing and balloon voyages, or much increased, as in diving-bells, or pneumatic-tubes and chambers used in pier driving below water, marked effects are produced upon both the breathing and blood circulation of men. Under very low pressures, the pulse rate and respirations are at first increased, becoming afterwards gradually slower and stronger. After some lengthened exposure to low atmospheric pressure, the thorax and lungs become widened with deep respiration. The general results of prolonged residence under low atmospheric pressure are good. The thinning as it were of the atmosphere and the lessened amount of oxygen available stimulates a development of the inspiratory act and a more vigorous vascular system. These effects are well seen in the broad and deep chests with well-developed muscles of all mountain races. The effects of increased atmospheric pressure are more marked, as evidenced by the deafness, ear pains, and sense of tightness round the head which are experienced by those going down in diving-bells. In pneumatic chambers and tubes used for pier driving and laying the foundations of bridges, the pressure in the air-chambers is usually of from 3 to 4 atmospheres, and if due precautions are taken to neither increase nor lower the pressure too rapidly, no symptoms or inconvenience are experienced by workmen when employed in them for hours together. What accidents and ill effects have occurred are chiefly in the form of prickings, muscular pains, nose bleedings and paralysis, and these have occurred commonly after leaving the high-pressure chambers or tubes, and when the reduction of pressure has been too rapid. Very few unfavourable effects appear to occur under the actual high pressure. The great danger in all these cases appears to be in the too sudden reduction of pressure. If time be given, the body seems to be

quite able to accommodate itself to the extreme variations of pressure; thus in a balloon ascent made by Messrs. Glaisher and Coxwell, these observers were able to withstand as low a pressure as indicated by 8 inches of mercury, while, on the other hand, men who worked in sinking piers for the Forth Bridge did so in air-chambers in which the barometer stood as high as 72 inches. These two instances give a range of atmospheric pressure extending over 64 inches, supportable by man.

In everyday life, the variations of barometric pressure, though rarely extending over a greater range than 3 inches, have a practical value as indicating the general character of the weather and the probable presence or absence of rain. It has already been explained how rain is dependent upon the presence of moisture in the air, and upon how well the air can retain that moisture. It has, too, been explained that when dry air receives moisture its volume increases, with the result that an amount of air which, when dry, measures 1 cubic foot, and weighs, at 50° F., 546·8 grs., becomes, when saturated with watery vapour at the same temperature, 1·0121 cubic feet, with a weight of 550·9 grs.; so that 1 cubic foot of the saturated air weighs but 544·3, or 2·3 grains lighter than it did when dry. It is this physical fact of moist air weighing lighter than dry air that causes the barometer to fall in consequence of lessened atmospheric weight when much moisture is present, and, consequently, rain imminent. It must, however, be remembered that other causes than moisture will often affect the barometer, notably wind, though, in the main, its movements are dependent largely upon the presence or absence of watery vapour in the air. It was the early recognition of this fact that led to the use of the barometer as a weather-indicator. In former years the value of the barometric reading was necessarily limited to the particular spot at which it was noted; but recently, as the result of increased facilities of communication between one place and another, it is possible to obtain simultaneous readings of the barometer at any given time at several spots distributed over a wide area. Now, if these are recorded on a map, and lines be drawn between and connecting all places where the same pressure prevails, we obtain what is called a *synoptic chart*, made up of lines of equal barometric reading, or *isobars*, as they are termed. This is what is actually done in all the chief meteorological stations, and experience has shown that these isobars commonly assume certain typical forms or shapes, which are again usually associated with certain kinds of weather. It is upon these data and facts that the modern methods of weather forecasting are based.

Isobars, or lines drawn on a chart indicating places of equal

barometric pressure, are found to arrange themselves practically into seven different shapes called cyclones, secondary cyclones, V-shaped depressions, anti-cyclones, wedges of high pressure, cols and straight isobars; the general characteristics of each are shown in Fig. 91. The closeness of the isobars one to another, or the rapidity of changes in pressure, constitute what is called the "barometric gradient," and just as we measure and express a railway gradient as being 1 in 20, 1 in 100, and so on, so can we say that barometric gradients are so many thousandths of an inch in fifteen miles, or so many millimetres in one degree of the

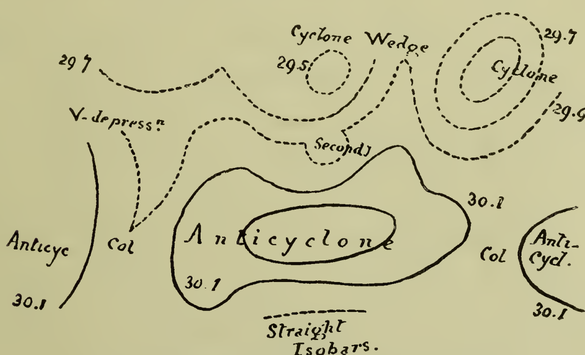


FIG. 91.—Diagram showing the chief types of isobars.

meridian. The steepness of the barometric gradients directly governs the velocity of the wind over any particular place, the wind's velocity being greatest at the localities of steepest gradient and *vice versâ*. In addition to this, if the wind's direction at each place be noted on a synoptic chart, it is found to be nearly parallel to the trend of the isobars, and tends to cross from the higher to the lower ones. This fact has found expression in what is known as Buys Ballot's law, namely, that if you stand with your back to the wind, the lowest pressure lies to your left and in front.

Cyclones.—An area of low pressure, and the whole system connected with it, is called a depression or cyclone, and in America "a low." As seen on a synoptic chart, cyclones are circles formed by concentric isobars, in which the outer lines mark a higher pressure than the inner ones; they constitute the most frequent arrangement of isobars in these latitudes (Fig. 92). They usually travel from west to east, at the rate of about twenty miles an hour, and are invariably associated with bad weather. From what has already been said, it is evident that the actual

pressure or height of the barometer is of little moment; the forces involved are due to the gradients or differences of pressure, and are greater the steeper the gradients. Hence a cyclone may be of a mild type, or be a gale or hurricane, according as to whether the gradients are gentle or steep. If we analyze the weather associated with a cyclonic disturbance, we find that the foremost portion of a cyclone area is always marked by stratiform clouds, moist heavy atmosphere, and the usual signs of coming rain, such as a pale moon, watery sun, dirty gloomy sky. As the cyclone

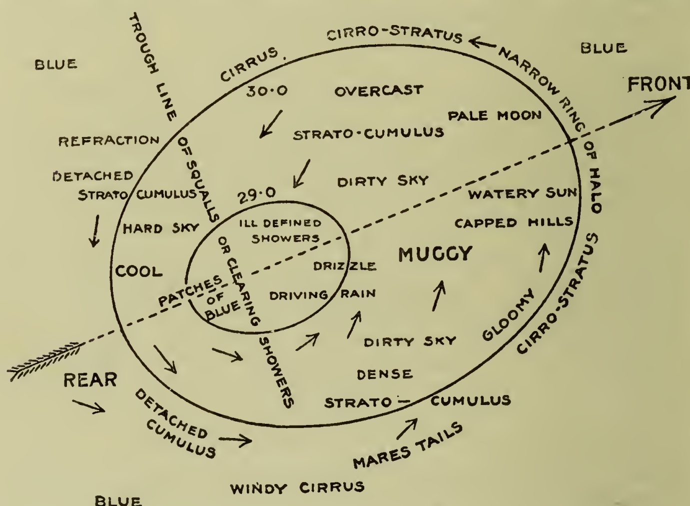


FIG. 92.—Diagram showing weather typical of a cyclone. (After Abercromby.)

advances, a drizzling gradually changes into a driving rain, accompanied in the trough or situation of lowest pressure by squalls of wind. As the cyclone area shifts its position or moves onward, the rain moderates into showers, followed by a brighter sky with cumulus clouds and a sharp brisk feeling in the air. If we study the barometer changes at different points in the path of a cyclone, it is at once obvious that in the fore part of the area of depression the barometer is everywhere falling, while in the rear part it is everywhere rising, and the turning-point, or line of lowest pressure, is what is called the trough. A cyclone may be compared to a cup-shaped hollow, the isobars being simply contour lines. The extent or area of a cyclonic disturbance may vary from ten or twenty to some thousands of miles, covering even the whole Atlantic or the greater part of Europe. Cyclones are usually oval and not circular in form, their longest diameter

being in these latitudes in a direction nearly W.S.W. to E.N.E. in the majority of cases. When the dimensions become great, especially if the system be much elongated, a cyclone frequently breaks up into two, three, or even more separate centres of depression. Large cyclones are, of course, much modified in both form and position by the variations of the deflecting force due to the rotation of the earth, and arising from difference of latitude. As a rule, the higher the latitude, the greater is the average size of cyclones. In the tropics, cyclones are usually smaller and circular. It is important, however, not to confound small cyclones with either waterspouts or tornadoes, which are too small to be much influenced by the rotation of the earth, besides which they are special phenomena of a distinct nature. The direction of the wind is, in all cyclones, obliquely across the isobars, and may be described as blowing spirally into the area of low pressure towards the centre, and from the central area in an upward direction. The particular angle at which the incurving of the wind takes place in a cyclone depends on the friction between the air-currents and the earth's surface, the angle being smaller the greater the friction. Thus, according to Ley, the angle between the direction of the wind and the isobars is 29° for coast stations, and 13° for inland stations, thus showing distinctly the increased effects of friction on land. It has already been stated that cyclones in these latitudes for the most part move in an easterly direction; when a westward motion occurs, it is usually slow and seldom long-continued. The advance of a depression is commonly in a direction perpendicular to the line of steepest gradient, so that the highest pressure lies to the right; while also the temperature is highest to the right of its track. The rate of advance of a cyclone varies within very wide limits, on the whole, deep depressions move faster than shallow. The average rate of motion of translation of cyclones over Europe is from twenty to thirty miles an hour, while in America they travel commonly as rapidly as fifty miles an hour. So far as is known, cyclonic storms and weather seldom or never originate within five degrees of the equator, but this intermediate tropical belt is the scene of extremely violent hurricanes, which have a tendency to move in a westerly or north-westerly direction, and, moreover, appear to behave according to laws too complex to be given in detail here. The general weather characteristics of a northern cyclone area are given in Fig. 92, which shows such an arrangement of isobars shifting in a north-easterly direction.

Secondary Cyclones are areas of low pressure formed by looped or incompletely circular concentric isobars with the lowest pressure in the centre. They have many weather features in common

with primary cyclones, moving like them mostly from west to east. They frequently follow primary cyclones, and their bad weather is usually associated with calm and stationary barometers.

V-shaped Depressions are angular intervals or areas with the lowest pressure in the interior, and frequently form between adjoining anticyclones, and are, as it were, a specialized form of cyclone, or even may form part of a cyclone. They have been aptly described as tongues of depression projecting from a cyclone situated to one side; in the northern hemisphere the point or tip is usually towards the south. These V's commonly move from east to west, and the weather experienced by an observer over whom one of these areas of depression drifts is from blue sky to cloud, later on rain with a falling barometer and south-west wind, then a squall, during which the wind jumps round to north-west, followed by a rapidly clearing sky and a rising barometer. This type of isobars is always associated with squalls or thunderstorms, an historical instance being one of exceptional severity, which occurred on March 24, 1878, and which was the cause of the sinking of H.M.S. *Eurydice* off the Isle of Wight. Not only secondary cyclones but V-shaped depressions are in general most uncertain in their movements, and their occurrence is consequently very difficult to foretell. The extreme rapidity with which they travel at times, and the violence of the wind and rain developed within them, render them a source of great danger to both life and property. The peculiar summer thunderstorms of Central Europe and America are nearly always associated with V-shaped depressions.

Anticyclones.—These are areas of high pressure formed by more or less circular isobars, with the highest pressure in the centre. They differ from all other arrangements of isobars in tending to remain stationary and, too, to extend over large areas. The air is calm and cold in the centre, while on the borders the wind blows round the centre spirally outwards in the direction of the hands of the clock; thus, on the east side the wind comes from the north, on the south from the north-east, on the west from the south-east, and on the north from the west. In describing the cyclonic system it was explained how the wind in the centre of that system was an ascending current; that wind circulation is compensated by an equivalent descending current in what is in all respects the opposite of the cyclone, namely, the anticyclone. The characteristic circulation of the air in this is therefore exactly the reverse of that in a cyclone: it blows in the same direction as the hands of the clock, more spirally outwards from the centre at or near the surface of the earth, and inwards towards the centre at the level of the highest clouds. In anti-

cyclonic systems the barometric gradients are slight, and the normal wind circulation usually disturbed or disguised by accidental or local causes. The general weather features of an anticyclone are given in Fig. 93, from which it will be seen that they are the exact opposite of cyclonic conditions, being blue sky, dry cold air, a hot sun, little or no wind, and a hazy horizon—in fact, fine weather. The diagram shows in one half the summer characteristics of an anticyclone, in the other those of winter. Certain regions of the globe are remarkable for the existence of permanent and recurrent anticyclone systems. There is a

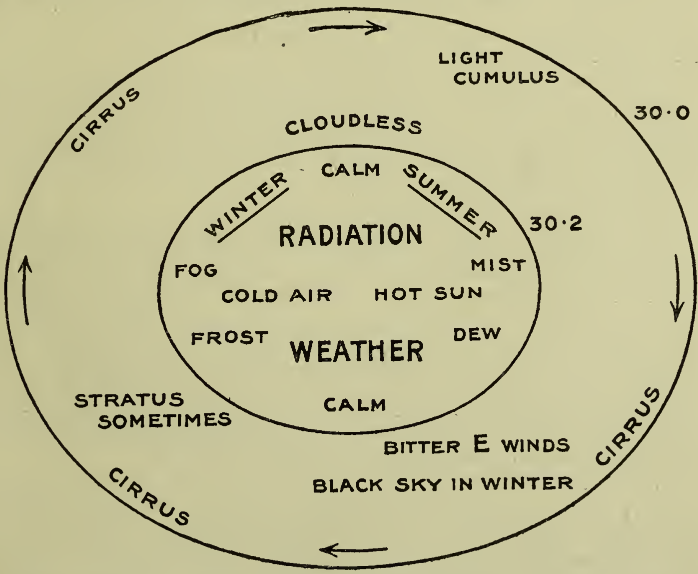


FIG. 93.—Diagram showing weather typical of an anticyclone. (After Abercromby.)

permanent area of high pressure near latitude 30° north, called the Atlantic Anticyclone, which varies in extent from month to month, attaining its greatest intensity in summer and least in winter. Another permanent area is that over the large land surface of Asia and Eastern Europe in which the pressure is usually excessive during winter. It is the existence and more or less permanency of these two large areas of high pressure which combine to give a north-westerly gradient towards a stationary low-pressure centre near Iceland and to govern the motions of cyclones, which tend to skirt round their borders in an easterly direction. It is important to remember that, while an anticyclone

system compensates a cyclone in the matter of transferring air from one level to another, there is no mutual relation between them in the sense of cause and effect.

Wedge-shaped Isobars usually point to the north and indicate areas of high pressure moving along between two adjacent cyclones. Though very usually associated with fine weather, it is only temporary because wedges of high pressure are never stationary, and are commonly followed by well-defined cyclonic areas. So far as weather is concerned we may regard the two sides of the wedge as the rear and front of cyclones, and the wedge itself as a mere projecting tongue of an anticyclone. The wide end of the wedge is often associated with fog, and the narrow end with thunderstorms or showers.

Cols, or necks of comparatively low pressure, generally lie between two anticyclonic areas. Over them the weather is dull, gloomy, and stagnant, while in summer violent thunderstorms are frequently associated with them. Like the following, cols are essentially intermediate systems.

Straight Isobars are those without any curve, and may trend in any direction. This arrangement of isobars only marks the position of a barometric slope, and does not enclose any area of either high or low pressure. This form is essentially temporary and an intermediate arrangement of the atmospheric circulation or pressure which precedes the formation of a cyclone. The weather associated with straight isobars is too transitional to be characteristic, but very frequently is that of a hard sky, with a blustering wind and an inclination to rain, such as one experiences as to remark that "when the wind falls it will rain."

What are known as squalls, or puffs of wind of varying intensity, appear to be caused by the sudden breaking of the cold dense upper layers of air through lower and warmer layers lying underneath, condensing the vapour in the latter and causing them to ascend. In contrast to them are the various kinds of squall attributable to the sudden ascent of masses of warm air; examples of this phenomenon we know, as the familiar dust whirls on a dry road, or the dust storms, waterspouts, and tornadoes of the tropics. As in the case of cyclones and anti-cyclones, the question, What is the cause of these descending and ascending air currents? is one of some complexity, and has not yet received an adequate explanation.

It must not be forgotten that all the foregoing forms of isobars are at any time liable to break up, or at least pass into new forms, so that, although every part of every shape of isobars has a characteristic weather and sky appearance, still, owing to their often rapid breaking up, forecasting of weather is not

always certain to come true. Cyclonic disturbances, for instance, are frequently diverted from their course by meeting a coast line or range of mountains, or even by the formation of areas of high pressure; so that their velocity is neither regular nor their direction of movement necessarily straight. On the other hand, experience shows that when advantage is taken of Transatlantic and other meteorological observations telegraphed to a central meteorological office, synoptic charts can be prepared of such magnitude and detail as to render weather forecasting comparatively successful in a great percentage of cases. All meteorological phenomena are practically the products or results of the circulation or motion of a moist atmosphere, and consequently forecasting weather is nothing more than saying how and where certain air currents or eddies will move, or when new ones will form, and whether they will be gentle or violent. From the rapidity with which meteorological changes take place, the use of telegraphy is absolutely necessary if any success is to be attained in forecasting, and even this information can be only of use in some central office presided over by an experienced forecaster thoroughly conversant with the motions of low-pressure areas in his own country. It will be readily understood that in some countries forecasting is easier than in others. Thus, in the temperate zone, where most disturbances move from the west, those countries will be best suited for weather forecasting which lie to the east of a well-observed land area. For this reason Norway and Germany are better placed for weather forecasting than either France or England. Large areas of land and water mainly determine the great areas of high and low pressure, hence Great Britain being placed where it is, on the boundary, so to speak, between anticyclonic and cyclonic systems, renders the prognostication of weather peculiarly difficult in these islands, more particularly as their geographical position precludes an early knowledge of cyclones forming over the Atlantic. Moreover, just as an outlying rock is exposed to the wash of every sea, so is England exposed to the disturbing influences of every type of European or Atlantic weather, and has, in consequence, more unsettled weather than any other part of Europe.[1]

[1] For further practical information on this subject, see R. H. Scott, "Weather Charts and Storm Warnings," 3rd ed., Longmans, 1887; also Abercromby, "Weather," Kegan, Paul & Co.; and Dickson, "Meteorology," Methuen and Co., 1893.

CHAPTER X.

VITAL STATISTICS.

PROBABLY no single cause has contributed more to the attention now paid to questions of public health than the careful collection of the statistics of births and deaths, and of the causes of death which have been collected and published by the Registrar General's Office in England during the past fifty years. These collections of figures and facts are usually spoken of as vital or health statistics, because they are so intimately associated with the various problems relating to the health and chances of life which the community enjoys. So valuable has been the work done, that we are now able to determine with some precision the causes and limits of mortality, and by the study and analysis of the collection of facts known as vital statistics to apply them as tests of the health of the communities to which they refer.

The chief vital statistics, bearing upon public health, relate in detail to past and present facts concerning populations, age and sex distribution, births, marriages, deaths, diseases, duration of the hours of occupation and general social conditions, such as the health of each class of the community as judged of by the expectation of life at given ages. Statistics of sickness, apart from mortality, have as yet not been attempted, chiefly on account of the difficulty in collecting the data with accuracy.

Population.—The very first necessity is to know what is the precise number of the people. Our knowledge upon this point in each place in Great Britain depends primarily upon the census returns which have been made regularly and with increasing care every ten years since 1801. It will be at once obvious that the facts relating to the numbers living of each sex and age periods and the numbers employed in certain callings can only be accurately known in actual census years, and making from them estimates for intermediate years. An interval of ten years between the takings of the census is now acknowledged to be too long, and it is probable that if our population statistics are to remain in any way accurate, more frequent enumerations of the people will need to be taken, and even then certain inaccuracies are sure to exist, due chiefly to the imperfect education of large numbers of householders and heads of families; these defects of information collected relating especially to occupations and ages. It is remarkable what a large number of people do not know their precise age; these persons generally giving their age in census returns in some multiple of ten. Another source of

error and perplexity in all census returns is the too frequent wilful misstatements made by women, owing to their desire, for various reasons, to be thought between 20 and 25 years of age. This is shown by the fact that in each successive census, the number of women returning themselves as between 20 and 25 is larger than the number of girls returned in the census of ten years before as between 10 and 15 years of age. The former being only the survivors, after the lapse of ten years of these latter, they should of necessity be fewer in number. The male sex is not altogether free from blame in the same matter, though the bias goes in the opposite direction. Thus, men of the poorer classes, who have passed the age of 60, constantly overstate their age for the sake of certain definite advantages, such as getting outdoor relief, or, if entering the poor-house, gaining some special privileges not granted to their juniors. Some really old people often exaggerate their age in order to appear as centenarians.

In attempting to estimate the population of any given locality for any year intermediate between the collection of census returns, it is necessary to calculate the probable decrease or increase of the particular population by comparing the numbers of the latest enumerations. Thus, say a town had in 1881 a population of 35,626, and in 1891 one of 38,754, and it was required to know its estimated population in June, 1896: it is only fair in such a case to assume that the 1896 population will be greater than the 1891, and, if we further assume that the increase will be at the same rate as between 1881 and 1891, by taking the difference between the 1881 and the 1891 populations and dividing by ten we get the annual increase of population for that town. Inasmuch as the census is always taken in the first quarter of the year, and we require the population at the end of June, 1896, an interval of $5\frac{1}{4}$ years will have elapsed since the last census; if, therefore, we multiply the annual increase of population, which in this example is $\frac{38754 - 35626}{10} = 312{\cdot}8$, by $5{\cdot}25$, we get an increase of 1642 to be added to the 1891 population, giving an estimated population of 38,754 + 1642, or 40,396 for the middle of 1896.

The foregoing method of calculating an estimated population is fallacious, as it presumes the increase or decrease will be as in an arithmetical progression. The true law of population increase or its decrease is that of a geometrical progression, and is very suitably compared to the increase of a sum of money at compound interest. The increase in x years is derived from the increase in one year by multiplying 1 *plus* the annual rate of increase x times into itself. If the increase in one year be 1·5 per cent., 1 becomes 1·015 in one year, and 1·015 multiplied x times into itself will give

the increase in x years. To obtain, therefore, the annual rate of increase in x years, the *xth root*, and not the *xth part* of the x rate of increase, must be taken. It is on this assumption, that the increase or decrease of a population proceeds as in a geometrical and not in an arithmetical progression, that the Registrar-General calculates the estimated populations for London and other large towns, as well as for the whole country, for intercensal years. On this basis the calculations are more conveniently performed by logarithms in the following manner.

Taking the same example as above, we find the logarithm for the 1891 population, or log 38,754 = 4·5883165, and deduct from it the logarithm for the 1881 population, or log 35,626 = 4·5517671; this gives 0·0365494, which is the logarithm of the decennial increase. Dividing this by 10 gives us 0·0036545, or the logarithm of the annual increase, and a quarter of this is 0·0009136, or the logarithm of the quarterly increase. By adding together the logarithm of the 1891 population and five times the logarithm of the annual increase and the logarithm of the quarterly increase we get the logarithm of the mid year 1896 population, or 4·6075026, which, by reference to a set of tables, = a population of 40504, or somewhat higher than the estimation made by that of a simple arithmetical progression.

Unfortunately, these assumptions as to a uniform increase or decrease of numbers are largely arbitrary or conjectural, and but rarely agree with the actual facts as found by the next census. Thus the population of London as estimated in 1891 by the Registrar-General was 4,441,993, but when actually enumerated by that year's census was found to be nearly a quarter of a million less, or only 4,221,452; that is, the rate of increase of population during the ten years 1881–91 had been much less than in the preceding decennial period. In a similar way the total population of England and Wales at the census of 1891 was found to be only 29,001,018, showing a rate of increase during the ten years 1882–91 of 11·65 per cent. as against 14·36 between 1872–81, giving in fact the lowest rate of increase recorded since the systematic taking of a census was begun in 1801. Had the 1882–91 rate of increase been the same as in 1872–81, the population at the last census would have been greater than it proved to be by more than 701,000.

The same thing was found to have occurred in regard to the populations of most of the large towns, with the result that their calculated death-rates had been returned too low. It is chiefly owing to errors in either under or over estimating the population that faulty estimates of the birth- and death-rates have occurred; so true is this, that any very excessively high or low birth- or

death-rate is to many persons highly suggestive of the estimated population-return being wrong.

As the Registrar-General has pointed out, the official method of calculating populations by the assumption of an equable rate of growth is only trustworthy in the case of very large communities, where any abnormal increase in one direction is sure to be counterbalanced by an abnormal decrease in another. It is hardly suited for very small communities, where growth is very often most irregular and spasmodic.

A moment's reflection will show that many circumstances may help to quicken or slow the increase of a population. The increase in any given population may be either *natural* or *actual*. The former is merely the excess of births over deaths, while the latter is dependent upon the balance between births and immigration on the one hand and deaths and emigration on the other. The facts revealed by the last census, in 1891, showed a decline in the natural increase of population for England and Wales; this was not due to any increased mortality, but rather to a decline in the birth-rate, which was low beyond precedent. For the whole country the actual increase, as shown by the last census, also showed a decline, due mainly to an excess of emigration over immigration during the last decennium. As a general rule, in towns the *actual* increase is greater than the *natural*, simply because there is a natural tendency for people to migrate from rural to urban districts; and with regard to such local migrations, at present we have no available or systematic record. It is well known that in times when trade is bad in certain localities, a considerable movement of the population occurs to other parts, and *vice versâ*.

Although not officially recognized by the Registrar-General, there are several methods of checking estimated populations, which, if used judiciously, are of great value. Amongst such are examinations of inhabited houses as ascertained from the rate-books, and then, assuming the density to remain the same, to multiply the number of inhabited houses by the average number of persons per house. Care, however, must be taken to allow for any marked change in the class of new houses built, whether containing fewer or more occupants than others, and, too, to allow for block buildings, flats and large hotels, all of which are liable to seriously affect statistical results. Another useful method for checking the calculation of a present population, suggested by Dr. Newsholme, may be derived from the birth-rate of a place. It is based on the assumption that the birth-rate remains the same for a series of years as it was found to be at the time of the last census. Thus, in Wandsworth, the average birth-rate for the

decennium 1872–81 was 35·68 per 1000, and the number of births in 1881 was 7582, therefore assuming that 35·68 was the number of births from one thousand of population, 7582 was the birth-rate of 212,500 people; or, $\frac{7582 \times 1000}{35 \cdot 68} = 212{,}500$. As a matter of fact, the actual census return for Wandsworth, in April, 1881, was 210,434, an astonishingly close approximation of results.

The following table shows the difference between the estimated and enumerated populations of some large towns in 1891, as taken from the Registrar-General's return, as well as the actual increase in their populations which has taken place.

Town.	Enumerated population at census of 1881.	Enumerated population at census of 1891.	Estimated population in middle of 1891.	Excess or defect of column 2 over column 3.	Actual increase or decrease of population.
Birmingham . .	436,971	478,113	469,003	+ 9,110	+ 41,142
Blackburn . .	104,014	120,064	125,874	− 5,810	+ 16,050
Bolton . . .	105,414	115,002	117,034	− 2,032	+ 9,588
Bradford . . .	194,495	216,361	246,101	− 29,740	+ 21,866
Brighton . . .	107,546	115,873	125,539	− 9,656	+ 8,327
Bristol . . .	206,874	221,578	235,171	− 13,593	+ 14,704
Cardiff . . .	82,761	128,915	121,477	+ 7,438	+ 46,154
Derby . . .	81,165	94,146	103,269	− 9,123	+ 12,981
Halifax . . .	81,117	89,832	82,998	+ 6,834	+ 8,715
Huddersfield .	86,502	95,420	101,080	− 5,660	+ 8,918
Hull	165,690	200,044	219,812	− 19,768	+ 34,354
Leeds . . .	309,119	367,505	370,261	− 2,756	+ 58,386
Leicester. . .	136,593	174,624	158,266	+ 16,358	+ 38,031
Liverpool . .	552,508	517,980	620,443	− 102,463	− 34,522
Manchester . .	462,303	505,368	506,325	− 957	+ 43,065
Newcastle . .	145,359	186,300	165,016	+ 21,284	+ 40,941
Norwich . . .	87,842	100,970	96,202	+ 4,768	+ 13,128
Nottingham . .	186,575	213,877	252,217	− 38,340	+ 27,302
Oldham . . .	111,343	131,463	151,158	− 19,695	+ 20,120
Plymouth . .	73,858	84,248	79,339	+ 4,909	+ 10,390
Portsmouth . .	127,989	159,251	144,671	+ 14,580	+ 31,262
Preston . . .	96,537	107,573	106,141	+ 1,432	+ 11,036
Salford . . .	176,235	198,139	251,024	− 52,885	+ 21,904
Sheffield . . .	284,508	324,243	338,543	− 14,300	+ 39,735
Sunderland . .	116,526	131,015	138,859	− 7,844	+ 14,489
Wolverhampton.	75,766	82,662	84,277	− 1,615	+ 6,896

Age and Sex Distribution.—This is sometimes spoken of as the constitution of a population, inasmuch as it shows the proportion in which males and females, and persons of different ages or of different callings enter into the composition of the community. These figures and facts are of course only obtained at each census, and generally may be taken to remain constant till the next census.

The effect which these facts have upon mortality statistics will be explained later on; at present, allusion need only be made to the very marked difference which exists in the age distribution between the populations of town or urban, and those of rural districts. The 1891 census gives for England and Wales the following age and sex distribution of the population per million persons of all ages:—

	English Urban Districts.			English Rural Districts.		
	Persons.	Males.	Females.	Persons.	Males.	Females.
All ages . . .	1,000,000	479,268	520,732	1,000,000	498,131	501,869
0 to 5 . .	122,524	60,906	61,618	122,521	61,045	61,476
5 ,, 10 . .	115,343	57,428	57,915	121,504	60,859	60,645
10 ,, 15 . .	109,405	54,149	55,256	115,639	59,133	56,506
15 ,, 20 . .	103,429	49,865	53,564	97,405	52,204	45,201
20 ,, 25 . .	95,551	44,260	51,291	80,155	39,782	40,373
25 ,, 35 . .	157,413	74,520	82,893	134,266	65,608	68,658
35 ,, 45 . .	117,719	56,781	60,938	107,193	52,375	54,818
45 ,, 55 . .	85,188	40,353	44,835	88,420	42,999	45,421
55 ,, 65 . .	53,264	24,175	29,089	67,106	32,685	34,421
65 ,, 75 . .	29,658	12,721	16,937	45,658	22,090	23,568
Over 75 . .	10,506	4,110	6,396	20,133	9,351	10,782

This table shows that, as compared with the country districts, in the towns of England and Wales there is a great excess of persons from 15 to 45 years of age, and a small proportion of children between 5 and 10 years of age. The probable explanation of these figures is the persistent immigration of young adults from the country to the urban areas in the one case, and the higher infantile mortality of the towns than of rural districts in the other. The proportion of females to males, of all ages, is much higher in towns than in the country, being 109 to 100 in the former, but only as 101 to 100 in the latter. These proportions are only manifest after the 10 to 15 age period, when the girls begin to migrate into the towns as domestic servants. The migration of girls into towns is soon followed by that of boys, with the result that the unequal proportion of the two sexes in towns in the 15 to 20 age period is considerably reduced, and continues to be so during all the more active working ages, or the period from the end of the 25th to the end of the 45th year of life. In the later years of life, the disproportion between the sexes in the towns again increases, so much so that in the 55 to 65 years period the women are 20 per cent. more numerous in towns than the

men, but only about 5 per cent. more numerous in the country. In the 65 to 75 period the excess is 33 per cent. in the towns, and only 7 per cent. in the country; while in the over 75 years period the excess of women becomes 22 per cent. in the towns, and only 6 per cent. in the rural districts.

As the Registrar-General has pointed out, this increasing excess of females in the late-age periods, so far as it is common to both towns and country, is, of course, due to the fact that women are longer lived than men, that is, they survive when the men die off. The greater excess of women over men in towns than in the country is less easy of explanation. It may be due to the fact that men, as they get old, leave the towns where the struggle for existence is so much the more keen, and retire into the country more rapidly than do the women; or it may be due to differences between the conditions of town and country life being more hostile to old men than to old women. Possibly both causes are at work. We know that for some reason or other urban life is exceptionally fatal to elderly men, and that towns offer, even to those in advanced age, more chances of comparatively easy work to women than to men; hence there is more inducement for women than for men to remain in the towns when they have grown old, especially as town life is much less healthy for men than for women. The practical importance of this question of age and sex distribution in vital statistics will be apparent when we come to consider the value of death-rates.

Birth and Marriage Rates.—The Births and Deaths Registration Act of 1874 compels every birth to be registered within 42 days of its occurrence. The number of births per 1000 persons living, or birth-rate, as it is so called, averaged 32·5 per 1000 in England and Wales, during the decennium 1881–90, the highest rate of 36·3 ever recorded in this country having been reached in 1876, and the lowest 30·2, in the year 1890. For the year 1892 it was 30·5. The birth-rate naturally varies greatly in different towns or localities, being higher in towns and during times of commercial prosperity, and of course lower in rural districts and during periods of trade depression. Bad trade and bad harvests also diminish the number of marriages, and consequently lower the number of children born.

The birth and marriage rates are readily found by a simple proportion sum; thus, if the population of a town be 13,621, and the number of births and marriages during the year are respectively 441 and 215, then $\frac{441}{13621} \times 1000 = 32{\cdot}3$ birth-rate per 1000, and $\frac{215}{13621} \times 1000 = 15{\cdot}7$ marriage-rate per 1000. This method of stating the ratio of births, marriages, or deaths in one year, as per thousand persons living in a place is the most

usual and convenient, but occasionally it may be necessary to compare these rates for shorter periods, say weeks, months, or quarters; in which case it is done in the following way. Suppose it is required to know the birth-rate during $\frac{1}{n}$ part of a year, then—

$$\frac{\text{Number of births during the period in question}}{\text{Population in the middle of the year}} \times n \times 1000 =$$

birth-rate of period in question. Taking the preceding example, and required the birth-rate during one week or $\frac{1}{52 \cdot 17747}$ part of a year, during which period 10 births have taken place, we get $\frac{10}{13621} \times 52 \cdot 17747 \times 1000 = 38 \cdot 19$ or birth-rate.

When comparing one community with another, to be strictly fair, the birth-rate should be calculated on the total population only after it has been reduced to a common or normal constitution as regards sex, age and marriage. This is best secured by calculating the birth-rate on the number of women between 20 and 40 years of age who constitute the great majority of child-bearing mothers. More males appear to be born than females, in the proportion of 104 to 100. The number of illegitimate children born is diminishing; formerly it was as much as 5 per 1000; in 1892 the proportion was as low as 1·3 per 1000 persons living. This illegitimate birth-rate varies much in different districts; thus the registration counties in which the proportion of illegitimate to total births was highest, were, as usually, Norfolk, Herefordshire, Shropshire, Cumberland, Westmoreland, and North Wales.

Closely connected with the birth-rate is that of the marriage-rate, and both are intimately involved in the question of population increase. In this country, the number of married persons per 1000 of living has averaged during the last 50 years something like 16 or 17; but of late years it has steadily fallen. In 1892, 15·4 persons per 1000 living married; the rate in 1886 was only 14·2. Like the births, the marriages usually closely follow the fluctuations in commercial prosperity. The slight rise in the marriage-rate in 1891 coincided, however, contrary to the almost universal rule, with a considerable decline in the value of British trade. The mean age of marriage seems to be, for males, 26; for females, 24; while the average number of children to each marriage is roughly 4½. In France and some foreign countries the production of children is deliberately restricted in relation to the possible maintenance of them at home; with the result that the total populations are diminishing. In this country, we

have no need to discourage the expansion of the population, for our colonies are in need of more inhabitants, and our industries of more work-people. In fact, it is the absence of such restrictions on population in Great Britain which has enabled us to establish our colonial empire and extend the British nation all over the world. It is as much a mistake to suppose that the inhabitants of a country are in proportion to their food, as it is to think that the productions of a country are in proportion to the number of its inhabitants. The truth is, the population that a country sustains, does not depend exclusively on the amount of subsistence existing in it at any one time, but rather that the produce of a country is limited chiefly by the character of its inhabitants, and the more civilized and cultured they are, the greater will be the products of their industry. Unfortunately population is often out of the place where it is wanted or could be most productive; but at no time can it be said that the population of the world is excessive. And as for any need to restrict the production of children as advocated by Malthus, it is as uncalled for as it is mischievous, and amounting as it does to a policy of depopulation, it means the gradual reduction of England, in the presence of the great continental nations, to the level of a second-rate power.

Death-rates.—By the Births and Deaths Registration Act of 1874, all deaths must be registered within five days of their occurrence. In 1892, the deaths registered in England and Wales were in a proportion of 19·01 to every 1000 persons living. In 1891, the rate was 20·2, or higher than that of any one of the ten preceding years, 1881–90, in none of which had the rate reached 20 per 1000; the average for England and Wales having been 19·1. The death-rate is obtained in exactly the same way as that for births; by multiplying the actual number of deaths from all causes into 1000 and dividing the product by the population; this is known as the general or gross death-rate. In a similar way as explained above for calculating the weekly or quarterly birth-rate, so is the annual death-rate for the week, month, or quarter obtained.

Thus, take a town with a population of 20,000 and the deaths in any week being 8, the annual death-rate for that week will be 11, or $\frac{8}{20000} \times 52{\cdot}17747 \times 1000 = 10{\cdot}87$. These so-called weekly death-rates are convenient for reports, but are not reliable data on which to compare the relative conditions of places, as much of the mortality often depends upon epidemics, weather, and other causes of a temporary nature. These death-rates, as published for each week by the Registrar-General, must therefore not be regarded as actual rates, but rather as annual rates

per 1000, representing the number who would die supposing the same proportion of deaths to population held good all through the year. Their chief value is for contrasting mortality rates of any given place at corresponding periods of some previous year. The value of the general death-rate has been much criticized on the ground that it is much influenced by movements of the populations, by the presence of large institutions, such as hospitals, by the age and sex distribution of the population, and by the birth-rate. All this is quite true, but still, if due correction be made, it is probably in the case of large populations, the most trustworthy test we have of relative vitality. The corrections most advantageously applied to general death-rates are: (1) for non-resident, or migratory people; (2) for age and sex distribution.

The correction for a migratory population is most difficult to apply, as it is not easy to trace and control the facts relating to visitors and immigrants. In the case of watering-places and favourite residential towns, corrections in this direction are most important, and are largely made by the officials from materials obtainable from the sub-registrars; but, even under the best supervision, considerable disturbance and fallacies to the statistics occur. Closely allied to the consideration of migration is the effect which public institutions, such as poor-houses or hospitals, exert on local death-rates, as the disturbance arising from them is due to migration into them from neighbouring districts. To meet this difficulty, the rule is to deduct the deaths of those inmates drawn from outside areas, at the same time adding the deaths of proper inhabitants of the place which may have occurred in other institutions outside the district. Each sanitary authority in London is supplied quarterly by the Registrar-General with particulars of death of their inhabitants in outlying districts, so that the deaths in all these cases may be apportioned to their proper districts. Unfortunately such accuracy does not pertain to rural districts, but it is to be hoped, in course of time, even this will be done. All general death-rates require to be corrected for age and sex distribution. Females live longer than males. It follows, therefore, that if two towns were in an equally healthy state, but that one of them contained a larger proportion of females than the other, the one with the lower proportion of females would have the higher death-rate. Similarly, there is a great tendency to death among infants; this liability to die reaching its minimum from between ten to fifteen years of age, and afterwards steadily increasing throughout life. In this respect, there was a remarkable increase of mortality at the advanced ages in 1890–91, due to the prevalence of epidemic influenza.

The following table shows the mean annual death-rates in England and Wales for 1871–80 and 1881–90 per thousand persons living at each age period :—

Age Group.	All Persons.		Males.		Females.	
	1871–80.	1881–90.	1871–80.	1881–90.	1871–80.	1881–90.
0–5	63·1	56·8	68·1	61·7	58·1	2·0
5–10	6·4	5·2	6·7	5·3	6·2	5·2
10–15	3·7	3·0	3·7	3·0	3·7	3·1
15–20	5·3	4·3	5·2	4·3	5·4	4·4
20–25	7·0	5·6	7·3	5·8	6·8	5·5
25–35	8·9	7·5	9·3	7·7	8·6	7·3
35–45	12·6	12·5	13·7	12·4	11·6	10·5
45–55	17·7	17·2	20·0	19·3	15·6	15·1
55–65	31·5	31·5	34·8	34·6	28·5	28·4
65–75	64·9	65·1	69·6	70·2	60·8	60·0
Over 75	161·6	154·8	169·1	62·2	155·8	147·4
All ages.	21·4	19·1	22·7	20·22	20·1	18·00

It follows, therefore, that a town, a large proportion of whose inhabitants were at the most viable age, would have a lower death-rate than a town equally healthy, in which the ages of the people were less favourable to long life ; just as it would be if the one town had a much larger population of females than the other. In order to neutralize these errors, the Registrar-General has devised a method by which they can be corrected.

This method, based primarily upon the death-rate of each sex at different ages throughout England and Wales, provides a series of factors by which the recorded death-rates of the great towns can be each multiplied so as to make them comparable with that of England and Wales. By the use of these factors, the recorded gross death-rate of any of these towns can be lowered or raised to what it would be if the age and sex distribution of that particular town were the same as that of England and Wales generally. This new rate is called the *corrected death-rate.* The factor employed is practically the expression of the ratio which the recorded death-rate bears to an empirical (arbitrary) *standard death-rate,* calculated on the hypothesis that deaths at each age period were at the same rate as in England and Wales during the decennium 1881–90, the death-rate at all ages in England and Wales during that period having been 19·15 per 1000. Owing to the proportions of persons of low mortality being excessive in

most towns, their recorded death-rates are too low, and in consequence the factor for their correction is in most cases above unity, the only exceptions being Plymouth and Norwich. The table below gives these factors for the chief towns as issued by the Registrar-General in 1894, along with their recorded and corrected death-rates per 1000 living in 1893.

Towns in the order of their corrected death-rates.	Standard death-rate.	Factor for correction for sex and age distribution.	Recorded death-rate, 1893.	Corrected death-rate, 1893.	Comparative mortality figure, 1893
England and Wales .	19·15	1·0000	19·17	19·17	1000
England and Wales less the 33 towns	19·45	0·9845	17·90	17·62	919
33 towns	17·71	1·0813	21·57	23·32	1216
Croydon	18·37	1·0424	16·30	16·99	886
Norwich	19·99	0·9579	19·28	18·47	963
Brighton	18·94	1·0110	18·42	18·62	971
Portsmouth . . .	18·73	1·0224	18·22	18·63	972
Halifax.	17·20	1·1133	17·36	19·33	1008
Bristol	18·33	1·0447	18·93	19·78	1032
Nottingham . . .	17·81	1·0752	18·46	19·85	1035
Huddersfield . . .	16·47	1·1627	17·20	20·00	1043
Derby	17·36	1·1031	18·24	20·12	1050
West Ham . . .	17·75	1·0788	18·91	20·40	1064
Plymouth	19·70	0·9720	21·25	20·66	1078
Gateshead	17·83	1·0740	19·30	20·73	1081
Swansea	17·53	1·0924	19·62	21·43	1118
Leicester	17·64	1·0855	20·01	21·72	1133
Cardiff	17·16	1·1159	19·68	21·96	1146
Birkenhead . . .	17·42	1·0993	20·54	22·58	1178
London	17·97	1·0656	21·31	22·71	1185
Newcastle-on-Tyne .	17·58	1·0892	21·00	22·87	1193
Hull	18·23	1·0504	21·84	22·94	1197
Sunderland . . .	18·25	1·0493	22·53	23·64	1233
Bradford	16·73	1·1446	20·96	23·99	1251
Oldham	16·72	1·1453	21·01	24·06	1255
Birmingham . . .	17·33	1·1050	21·98	24·29	1267
Wolverhampton . .	18·30	1·0464	23·27	24·35	1270
Leeds	17·28	1·1082	22·29	24·70	1288
Sheffield	17·22	1·1120	22·31	24·81	1294
Burnley	16·67	1·1487	21·88	25·13	1311
Blackburn	17·05	1·1231	23·28	26·15	1364
Salford.	17·03	1·1244	24·08	27·08	1413
Bolton	16·90	1·1331	24·12	27·33	1426
Manchester . . .	16·90	1·1331	24·90	28·21	1472
Preston.	17·42	1·0993	26·37	28·99	1512
Liverpool	17·26	1·1094	27·34	30·33	1582

If the corrected death-rate in each town be compared with the death-rate at all ages in England and Wales, taken as 1000, it gives a number known as the *comparative mortality figure*, as shown in the last column of the preceding table. These figures may be expressed in another way, by saying that after correction has been made for differences of age and sex distribution, the same number of people that gave 1000 deaths in England and Wales in 1893, gave 1288 in Leeds, 1133 in Leicester, and 1512 in Preston. Or we can say that in 1893 the death-rate for the whole of England and Wales was 19·17; and the recorded death-rate for Blackburn is 23·28, with its factor for correction as 1·1231. Then $23{\cdot}28 \times 1{\cdot}1231 = 26{\cdot}15$ as the corrected death-rate for Blackburn, and $\frac{26{\cdot}15}{19{\cdot}17} \times 1000 = 1364$ as its figure of comparative mortality.

The calculations of infant and child mortalities demand special remark; particularly as it is by no means uncommon to find them worked out on the population, or on the number of deaths at all ages. The proper, the most simple and most accurate way is rather to utilize the birth returns, and calculate out the ratio of deaths of infants under one year to the number of actual births in the latter half of the preceding year and the former half of the current year. The greatest care should be given to child mortality, or the death-rate of those under five years of age, as it constitutes an important and instructive index of health conditions. In 1892, the proportion of deaths of infants under one year of age to 1000 registered births was 148. The rate differs widely in different counties and towns; the general rule being that the rate is lowest in the purely agricultural, and highest in the mining districts, and in those with textile industries. For the past ten years and more, three towns in particular have been the worst in this respect; they are Preston, Leicester, and Blackburn. The following table gives the number

Age	Of 100,000 born, the numbers surviving at each age.			Annual death-rates per 1000 living in each successive age period.		
	Three rural counties.	Five mining and manufacturing counties.	Three selected towns.	Three rural counties.	Five mining and manufacturing counties.	Three selected towns.
At birth . . .	100000	100000	100000	213	331	382
,, 3 months . .	94820	92051	90874	75	154	240
,, 6 ,, . .	93068	88574	85574	61	128	180
,, 12 ,, . .	90283	83081	78197	—	—	—

of survivors after a lapse of 3, 6, and 12 months out of 100,000 births respectively, in three agricultural counties (Herts, Wilts, and Dorset): in five mining or industrial counties (Stafford, Leicester, Lancashire, West Riding, and Durham); and lastly, in the three selected towns of Preston, Leicester, and Blackburn. The figures are based upon the returns for the years 1889–1890, and 1891.

It will be seen from these figures how high is the mortality among young children in these particular towns and industrial counties, as compared with the rural counties; put into round numbers it means that for 10,000 deaths in the agricultural counties, there would be 22,000 in the towns in each case out of 100,000 children born alive.

The chief causes of infantile mortality, common to every locality, are briefly: premature birth, congenital defects, hereditary tendencies, inexperience and neglect of mothers, industrial conditions, improper food, and overlaying.

A very frequent source of error in vital statistics is made in calculating the mean death or other rate of two populations or communities; these are often spoken of as *combined death-rates*. The error usually arises from failing to take into account the proportion which the two populations or groups bear to one another. Thus suppose two towns each contain 30,000 inhabitants, and have respectively mortalities of 22 and 16, their mean or combined death-rate would be $\frac{22 + 16}{2}$ or 19. But suppose one of the towns have 42,000 inhabitants and the other 18,000, and have respectively the above mortalities, their combined death-rate will then not be the mean of their two separate death-rates, but as follows:—

One town of 42,000 people	with a death-rate of	22	per 1000	= 924 deaths.
,, ,, ,, 18,000 ,,	,, ,,	16	,,	= 288 ,,
or 60,000 people give				1212 deaths,

and $\frac{1212 \times 1000}{60,000} = 20{\cdot}2$, the true combined death-rate per 1000.

Death-rates are said to be largely influenced by the birth-rate, and by densities of population. With regard to the influence of the birth-rate upon the death-rate much controversy has prevailed. To a great extent this has been unnecessary, and has arisen from a misconception as to the true meaning of the relation between the birth- and death-rates. If we imagine a population in which there has been a high birth-rate for one or more years, it is clear such must contain a larger proportion than usual of young children, and inasmuch the death-rate of young children is higher

than that of all others except the aged, the general death-rate of that population will be raised; but this condition is to a large extent counterbalanced by the fact that a high birth-rate implies the presence in that particular population of a large proportion of persons of the child-bearing age, that is, of an age period when the mortality is unusually low. So, again, if the high birth-rate be continued for any length of years, it means not only a large proportion of children and of persons at reproductive ages, but also of young adults, among whom a low rate of mortality also prevails. The real influence of the birth-rate upon the death-rate, therefore, is not one which can be well expressed as a low birth-rate causing a low death-rate, or a high birth-rate producing a high death-rate, but rather that the average age of a population governs the death-rate, and that the lower the mean age of the living, the lower should be the death-rate, and, by inference, that the death-rate really controls the birth-rate because the lower it is the more chance is there of there being a large proportion of persons at the child-producing ages. If a high death-rate follows a high birth-rate, it reasonably suggests an excessive infantile mortality; very often low death-rates and low birth-rates co-exist, but it does not follow that the one is necessarily caused by the other.

The influence exerted by density of population on mortality and death-rates has long been recognized. The density may be either expressed as so many persons to a square mile or as acres to a person. The late Dr. Farr found that the mortality increases with the density of a population; not in direct proportion to the density, but as their sixth root; while, according to Dr. Ogle, this influence of the density does not affect the mortality unless there be more than four hundred persons to the square mile. The practice of building back-to-back houses so prevalent in Yorkshire and Lancashire, and without provision for through ventilation, illustrates very clearly the evil effects of crowding populations, and has been well sifted by the reports of Dr. Barry and Mr. Gordon Smith to the Local Government Board in 1888. Increased density of population gives rise to filth conditions, to the more rapid spread of infectious diseases, phthisis, accident, and other evil conditions, the outcome of co-existent poverty and occupation. It is probably by and through these, rather than from mere overcrowding, that density of population in any way influences the death-rate of a community.

Causes of Death.—It is not sufficient to know the death-rate of a community; it is necessary to know and inquire what rates the different causes of death give when the deaths are distributed to their several classes. Although the death returns obtained from registrars are principally derived from certificates signed by

either doctors or coroners, and, as such, should be clear statements of the precise cause of death, still even now the cause of death in many cases is both vague and ill-defined. Each year, however, shows improvement in this direction, with the result that the registration of death-causes is becoming gradually more and more accurate and complete. Some idea of the mortality in England and Wales from the several classes of diseases during the last few years will be gathered from the following table :—

Causes of Death.	Rate per million living.					
	1892.	1891.	1890.	1889.	1888.	1887.
Zymotic diseases	2785	2706	2541	2456	2133	2702
Parasitic diseases	21	23	24	24	25	30
Dietetic diseases	79	83	81	67	63	64
Constitutional diseases	3168	3339	3374	3223	3166	3213
Local diseases	9801	10807	10364	9394	9643	9867
Violence	651	670	653	614	622	652
Developmental diseases	1657	1690	1611	1550	1569	1578
Ill defined and not specified causes	853	899	900	893	891	968
All causes	19015	20217	19548	18221	18112	19074

The death-rate from zymotic or special febrile diseases is an important fact to be noted among all communities, as it furnishes a very popular standard as to their general healthiness. But it will readily be understood that it is liable to great fluctuations according to the greater or less prevalence of one or other of those diseases, with the result that a so-called mean zymotic death-rate is often of little value. Thus, say in a given community the zymotic death-rate be excessive owing to the epidemic prevalence of the two zymotic diseases, measles and whooping-cough. Owing to these diseases not being either usually or truly dependent upon defective sanitary conditions, their excessive prevalence, as evidenced by an increased zymotic death-rate, furnishes less clue as to the health-condition of the community than would an equally high zymotic mortality rate, owing to such diseases as diphtheria or enteric fever, which are more directly the expression of faulty sanitary states.

Of late years the zymotic death-rate has shown a steady tendency to fall; but so far, the best endeavours of sanitarians

have not been able to get the death-rates of the chief diseases of this class much below the following rates per 1000 living, namely—

Diphtheria	0·1	Scarlet fever	0·4
Enteric-fever	0·2	Whooping-cough	0·5
Measles	0·3	Diarrhœa	0·6

and any excess above these rates is suggestive of something being defective in the general sanitary state.

Other influences which largely disturb death-rates are sex, age, and occupation. The mortality among women appears to be higher than among males for such diseases as rheumatism, anæmia, chlorosis, erysipelas; while for affections connected with childbirth, it is, of course, limited to the female sex. On the other hand, men die more than women when affected with such diseases as syphilis, diabetes, rickets, typhus, meningitis, and hydrophobia.

The influence of age upon mortality rates is very marked in certain diseases. Thus, phthisis or consumption is at its lowest prevalence between the ages of 5 and 12, but increases up to 47 years of age, after which it lessens. Small-pox mortality is highest in the first and twenty-fifth years, while diarrhœa, whooping-cough, measles, and diphtheria all have their highest death-rates during the first few years of life. Cancer is a disease which appears rarely to affect the young, but tends to increase after 28 years of age. Diseases connected with the heart and circulatory system increase in their mortality rates from birth upwards. The total death-rate, and the death-rates from affections of the nervous system, lungs, and bladder, all appear to be at their lowest between the tenth and fifteenth years of life.

Occupation.—The more recent investigations of Drs. Ogle and Arlidge have thrown considerable light upon the influence which occupation has upon mortality. Some callings are much less favourable to health than others; some again, while being relatively healthy, are dangerous. The chief circumstances which render certain employments more or less hurtful to health are, bad ventilation and overcrowding of work-rooms; exposure to weather, or extremes of heat and cold; inhalations of vapours, gases, or metallic, mineral or organic dust; overstrain, and mental anxiety; and intemperance. Many difficulties and fallacies underlie all comparative statistics of class mortalities, unless due allowance be made for the age at which such employments are followed, as well as the question of the class of person actually engaged, and the importance of differentiating between employer and employed.

The following table shows the comparative mortality amongst persons of various occupations as gathered from the more recent statistics :—

Occupation.	Mean Annual Death-rate per 1000 living.		Comparative Mortality Figure.
	Age 25–45.	Age 45–65.	Age 25–65.
All males	10·16	25·27	1000
Occupied males	9·71	24·63	967
Inn and hotel servants	22·63	55·30	2205
General labourers in London	20·62	50·85	2020
Costermongers and hawkers	20·26	45·33	1879
Cornish miners	14·77	53·69	1839
Potters and earthenware manufacturers	13·70	51·39	1742
Filemakers	15·29	45·14	1667
Watchmen, porters, and messengers	17·07	37·37	1565
Licensed victuallers and innkeepers	18·02	33·68	1521
Chimney-sweeps	13·73	41·54	1519
Cabmen and omnibusmen	15·39	36·83	1482
Brewerymen	13·90	34·25	1361
Hairdressers	13·64	33·25	1327
Professional musicians	13·78	32·39	1314
Bargemen and watermen	14·25	31·13	1305
Carters and carriers	12·52	33·00	1275
Cutlers and tool and needle makers	11·71	34·72	1273
Plumbers, glaziers, and painters	11·07	32·49	1202
Glass-blowers	11·21	31·71	1190
Butchers	12·16	29·08	1170
Law clerks	10·77	30·79	1151
Medical men	11·57	28·03	1122
Cotton operatives in Lancashire	9·99	29·44	1088
Wool and worsted operatives	9·71	27·50	1082
Printers	11·12	26·60	1071
Tailors	10·73	26·47	1051
Chemists and druggists	10·58	25·16	1015
Tobacconists	11·14	23·46	1000
Commercial travellers	10·48	24·49	996
Blacksmiths	9·29	25·67	973
Builders and bricklayers	9·25	25·59	969
Bakers and confectioners	8·70	26·12	958
Corn millers	8·40	26·62	957
Insurance agents	9·04	25·03	928
Artists, sculptors, and architects	8·39	25·07	921
Shoemakers	9·31	23·36	921
Tanners and fellmongers	7·97	25·37	911
Watch and clockmakers	9·26	22·64	903
Plasterers and whitewashers	7·79	25·07	896
Coal miners	7·64	25·11	891

Occupation.	Mean Annual Death-rate per 1000 living.		Comparative Mortality Figure.
	Age 25–45.	Age 45–65.	Age 25–65.
Grooms and private coachmen	8·53	23·28	887
Drapers and warehousemen	9·70	20·96	883
Barristers and solicitors	7·54	23·13	842
Booksellers and stationers	8·53	20·57	825
Carpenters and joiners	7·77	21·74	820
Fishermen	8·32	19·74	797
Grocers	8·00	19·16	771
Schoolmasters and teachers	6·41	19·98	719
Agricultural labourers	7·13	17·68	701
Farmers and graziers	6·09	16·53	631
Gardeners and nurserymen	5·52	16·19	599
Clergy, priests, and ministers	4·64	15·93	556

In attempting to judge the health of a community by statistical evidence, the greatest importance is attached to the following points, namely: The total corrected death-rate, the zymotic death-rate, and the infant mortality. All these have been discussed, and the various sources of error connected with them explained. But, besides these, certain other evidence is usually considered, mainly as a test of the mean or average longevity of the population. This evidence consists of facts relating to what is known as "the mean age at death," "the probable duration of life," and "the expectation of life."

The **mean age at death** is of course obtained by adding up the ages of persons dying, and dividing this sum by the total number of deaths. In this country, the mean age of death averages 42 for males, and 45 for females. This fact is, however, an imperfect and crude test or index of longevity, simply because it is so largely affected by the birth-rate. If the birth-rate be high, there will be in consequence a greater proportion of infants or young children in the population. These we know have a relatively high death-rate, with the result that the average age of death will be proportionately reduced.

The **probable duration of life** is practically the age at which exactly half of any given number of children born alive will have died; or, in other words, there are equal chances of their dying before and after that age. It is sometimes spoken of as the equation of life, or *vie probable* of French writers. All these terms are more or less unfortunate, as there is a probability for every possible duration of life. Regarded strictly as defined above,

the probable duration of life is of no great value as a test of longevity; it can only be obtained from what is called a life-table, and as so determined for England and Wales, gives the probable duration of life for each male 47 years, and for each female 52 years. The probable duration of life is often confounded with another statistical expression, called the *mean duration of life*, which is the probable or likely duration of life from birth, and, by French writers, called the *vie moyenne*. If we imagine an absolutely stationary population, that is, one in which age and sex distribution does not change, then, starting from birth, the mean duration of life would be identical with the mean age at death, and with the expectation of life as determined by means of life-tables. But such a stationary population is rare, and in an ordinary community whose numbers are constantly being disturbed by migration or other causes, the mean duration of life really signifies the present age in years *plus* the probable duration of life after having attained a given age, and which is more commonly called the mean after lifetime, or expectation of life. For comparative purposes, it is often more convenient to employ the term mean duration of life as indicating the expectation of life at birth; but if it is required to remove the disturbing influence of infant mortality, then the mean after lifetime, or expectation of life at a later age, must be taken. This expression, expectation of life, must not be taken to imply that any individual may reasonably *expect* to live a given number of years, because it has no true relation to the most probable duration of the lifetime of any given person. It merely shows the *average* number of years which a person, at a given age, lives, and in that sense constitutes the true measure of the chances of living which a mixed community has. Its estimation is made by means of what is called a Life Table, and which is nothing more than a table constructed from census figures on the basis of the number living and the number dying at each age. Such a table shows how many out of say a million persons supposed to be born at the same time will survive at the end of each year or term of years. The same table will also show the sum of the number of years which they live, and if this sum of these years be divided by the number living at any given age, the result will be the expectation of life for that given age.

The late Dr. Farr called a life-table a *biometer*, because it really represents "a generation of individuals passing through time," and measures the probabilities of life and death of this generation at birth, and of the survivors at each successive age-period, until the whole generation is extinct. In order to construct a life-table, it is necessary to have (1) particulars from a

census return of the number, age, and sex-distribution of a population ; (2) return of deaths for one or more years among this same population, grouped in the same ages or age-periods as have been adopted for stating the census population. A separate table is required to be constructed for each sex, and for this reason the death returns must be distinct for the two sexes.

A life-table can be constructed for either annual or quinquennial intervals; in most tables, an annual interval is adopted for the first five years, and after that five-year periods are taken. The first step is to calculate from the census returns the death-rate per 1000 living for each age or group of ages, and call this D. These deaths may be assumed to be evenly distributed over the whole age-period, so that half the deaths will occur in the first portion of the period, and the other half in the second portion; and the ratio of the final to the initial population is, $\frac{1000 - \frac{1}{2}D}{1000 + \frac{1}{2}D}$, which, when simplified, becomes $\frac{2000 - D}{2000 + D}$

For the construction of a hypothetical life-table, let us suppose that the mortality among infants in a given population is 100 for every 1000. It will be at once evident that if there be 1,000,000 babies born and living at the commencement of a given year, these will be reduced to 900,000 in the course of the year, and this number will commence the second year. Presuming that the data show that the death-rate among children in the second year of life is as high as 50 per thousand living, then applying the foregoing formula, we get $\frac{2000 - 50}{2000 + 50}$ or $\frac{1950}{2050}$ or 0·951019, and the 900,000 children at the beginning of the second year are reduced to 900,000 × 0·951219, or 856,097 at the beginning of the third year. In the same way, knowing the death-rates for the third, fourth, and fifth years of life, the actual numbers of children surviving at the end of those age-periods is calculated. Suppose now, by the end of the fifth year only 650,000 survive out of the original million, and we propose to continue constructing the life-table for quinquennial or five-year periods in place of annual intervals. The calculation is practically the same, substituting for the death-rate of each year the death-rate for each quinquennium. Presume the death-rate among persons aged 5 to 10 years to be 7, then applying the formula for the reduction of the population during this five-year period, we get $\left(\frac{2000 - 7}{2009 + 7}\right)^5$ or 0·965648, and at the end of this quinquennium, or by the end of the tenth year, the 650,000 will be reduced to 650,000 × 0·965648 = 627,671. This calculation can be repeated for each five-year period until there are no more survivors left.

The first life-table for the whole of England and Wales was constructed by the late Dr. Farr, on the death-rates of 1838–54. A later one was issued from the Registrar-General's office by Dr. Ogle, on the basis of the death-rates of 1871–80. The following table gives a portion of the results of this later calculation :—

Age.	Males.		Females.	
	Survivors at each age out of 1,000,000 born.	Expectation of life in years.	Survivors at each age out of 1,000,000 born.	Expectation of life in years.
0	1,000,000	41·4	1,000,000	44·6
1	841,417	48·1	871,266	50·1
2	790,201	50·1	820,480	52·2
3	763,737	50·9	793,359	53·0
4	746,587	51·0	775,427	53·2
5	734,068	50·9	762,622	53·1
10	708,990	47·6	738,382	49·8
15	696,419	43·4	724 956	45 6
20	680,033	39·4	707,949	41·7
25	657,077	35·7	684,858	38·0
30	630,038	32 1	658,418	34·4
35	598,860	28·6	628,842	30·9
40	563,077	25·3	596,113	27·5
45	522,374	22·1	560,174	24·1
50	476,980	18 9	520,901	20·7
55	424,677	16·0	477,440	17·3
60	365,011	13·1	422,835	14·2
65	297,156	10·6	356,165	11·4
70	222,056	8·3	277,225	9 0
75	144,960	6·3	190,566	6·9
80	77,354	4·8	108,935	5·2
85	30,785	3·6	47,631	3·9
90	8 015	2·7	14,225	2·9
95	1,183	2 0	2,533	2·2
100	82	1·6	225	1·6

It has already been stated that from a life-table the expectation of life can be readily calculated. That this is so will be perhaps more clearly understood by the following example. Taking the 1871–80 table, suppose it is required to find the expectation of life for males at the age 35. The rule is, to find the expectation of life at any age x, add together the years of life lived through by the whole of the life-table population after that age, and divide by the number of survivors at that age. If we refer to the table, and add together the numbers surviving at each age later than 35, we obtain the figure 3,133,710, which is the number of complete five-year periods lived through by the whole of the life-table population after 35 years of age. But

in addition to the five-year periods which a man lives through or completes, each of the 598,860 men surviving at 35 lives through some portion of that particular five-year period in which he dies, and this may be fairly taken to be half. Hence to the 3,133,701 quinquennia already obtained, we must add 598,860 half quinquennia, which gives us a total of 3,433,140 quinquennia, or 17,165,700 years of future life, and this divided among the 598,860 surviving males at age 35, gives them each an expectation of life of 28·6 years.

If we compare the old and new life-tables, it is at once noticeable that there is a greater expectation of life under the new table up to 19 years of age for males, and 45 for females. After these ages, the improvement appears to be less, possibly due to a greater death-rate under the new conditions amongst the elderly people; but this is so much counterbalanced by the saving in life during the earlier years that the total number of survivors up to about 70 for males, and 90 for females, is greater under the new table than in the old. The mean after lifetime at birth for both sexes is about $43\frac{1}{2}$ years in this country; while the probable duration of life lies between 45 and 50 for males, and between 50 and 55 for females.

The late Dr. Farr showed that the mean duration of life, or mean after lifetime, in the absence of proper life-tables, could be approximately calculated from the birth and death rates by the following formula, in which B = birth-rate and D = death-rate, while x = expectation of life at birth.

$$x = \frac{2}{3} \times \frac{1000}{D} + \frac{1}{3} \times \frac{1000}{B}$$

Say a town has a birth-rate of 32 and a death-rate of 28 per thousand, then applying this formula, we get—

$$\frac{2000}{3D} + \frac{1000}{3B} \text{ or } \frac{2000}{84} + \frac{1000}{96} = 34$$

as the mean expectation of life at birth under those conditions.

Willich gives another formula, in which x = the expectation of life at any age, a, between 25 and 75 years, then—

$$x = \frac{2\ (80 - a)}{3}$$

and applying this, say for calculating the expectation of life at 53 years of age, we get $\frac{2}{3}\,(80 - 53) = x$ or 18 years.

We have now discussed the chief kinds of statistical material generally at the disposal of the sanitarian, but before closing the subject, it is necessary to indicate the chief sources of fallacy in statistics, and the general limits within which they may be used.

In an ideal mass of statistics, the facts must (1) be all correctly observed; (2) they must be of the same kind and order; (3) they must be all localized both in regard to time and place; (4) they must be sufficiently numerous to give correct averages, and extend over sufficient length of time. It will be at once obvious that these various essentials are not easy to obtain. It has already been explained that while it is easy enough to ascertain correctly the numbers of a people during a census year, it is less simple to do so during intermediate years. Similarly, differences of degree or intensity, causation or virulence of diseases, render their comparison, by reducing their statistics to the same order and kind, extremely difficult. So, too, the importance of localizing statistics, both in respect of time and place, is made clear by pointing out the absurdity of attempting to construct a particular disease-rate for some health resort from the deaths of persons occurring there from that special affection. The fourth essential for an ideal statistical series is well expressed in the mathematical statement that the error diminishes as the square root of the number of observations; in other words, the smaller the total number of facts, the larger will be the relative percentage of errors displayed by them, and the larger the number of facts collected the smaller will be the margin of error.

The **mean** or **average** has been described as being a number which lies between the highest and lowest of a series of numbers, and has a definite dependence upon the whole of the series. The terms mean and average are often used synonymously; regarded mathematically, there are several kinds of means. Thus, the simple average, or *arithmetic* mean of four numbers, such as a, b, c, d, is conveniently written as $\frac{a+b+c+d}{4}$, but their *geometric* mean would be $\sqrt[4]{a\,b\,c\,d}$, while their *harmonic* mean stands thus: $\frac{4}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}$, and their *quadratic* mean is—

$$\sqrt{\frac{a^2+b^2+c^2+d^2}{4}}$$

Of course, if the terms of the series of numbers are unequal, then the quadratic mean will be the highest, next the arithmetic, and then the geometric and harmonic means; but if all the terms of the series are equal, then their means are equal too. The chief practical question in vital statistics is not so much either the value of a true or pure average, or arithmetical mean, or even the probable value of a fixed quantity, but rather the probable value of an *average* or variable quantity; the question being in most

cases how far the mean is a trustworthy approximation to the true value sought. One way of securing a correct mean, we have already seen, is by multiplying our facts; while a mode of testing the results of a statistical inquiry, is the determination of the *error*, or the divergence of the individual terms of the series from its mean. This is usually done by what the mathematician calls the law of error, and the following rules given by Professor Jevons are applicable for finding the probable error of a mean result:—

1. Draw the mean of all the observed results.
2. Find the excess or defect, that is, the error of each result from the mean.
3. Square each of these reputed errors.
4. Add together all these squares of the errors.
5. Take the square root of the sum.
6. Divide the square root by the number of results.
7. Multiply the quotient by 0·67449, or $\frac{2}{3}$.

Thus, suppose of the series 21, 32, 27, 25, 18, 33, whose mean is 26, we want to know the probable error of that mean. Now, the apparent errors of each number of the series from the mean are 5, 6, 1, 1, 8, 7; their squares are 25, 36, 1, 1, 64, 49; and the sum of the squares is 176. The nearest square root in whole numbers of this sum is 13, and this divided by 6, or the number of the series, gives 2·16, which multiplied by the factor 0·67449 yields 1·45 as the probable error of the mean of the series.

This calculation of the probable error may be described in another way by saying that it is the error of mean square multiplied by the mathematical constant 0·6745.

The error of mean square is the quadratic mean of the apparent errors, or the result of dividing the square root of the sum of the squares of the apparent errors by the number of terms.

Another test of the value of a series of terms or observations is the determination of their *mean error*, that is, the divergence of the individual terms of the series from its mean. This is conveniently performed in the following way: (1) Find the mean of the series, then find the mean of all the observations *above* the mean, and subtract the mean from it; this gives the mean error in excess; (2) find the mean of all the observations *below* the mean and subtract it from the mean; this gives the mean error in deficiency. Add the two quantities, and take the half; this is the mean error. In the preceding series of numbers, the mean

error of the individual terms is 4·6. It will be at once obvious that the greater the mean error the greater is the need for the series to be extended, in order to compensate for the unreliability of each term of the series, and that the value of any series of observations increases with their number and with their equality.

What is known as Poisson's formula is very frequently employed to determine the liability to error in vital statistics. Thus, say 500 persons are sick with a certain disease, and 165 of them, or 33 per cent., have died, and it is required to know whether these numbers are sufficiently great to say that this mortality rate is approximately constant and reliable for the particular disease in question; or whether the figures are too small to accept this death-rate as correct.

Poisson's formula says if μ = the total number of observations, made up of m in the direction of recovery, and n in the direction of death, then $m + n = \mu$; and that the true proportion of each group to the whole number of cases will be in the proportions represented by the formula $\frac{m}{\mu} \pm \frac{2\sqrt{2 \times m \times n}}{\mu^3}$ In the case cited, the probability of recovering is represented by $\frac{m}{\mu}$ or $\frac{67}{100}$ and of dying by $\frac{n}{\mu}$ or $\frac{33}{100}$

The possible error is expressed by the second part of the formula $\frac{2\sqrt{2 \times m \times n}}{\mu^3}$, and the smaller will be the value of this possible error the larger the total number of cases, or μ.

Applying this portion of the formula, we get $\frac{2\sqrt{2 \times m \times n}}{\mu^3}$ $= \frac{2\sqrt{2 \times 67 \times 33}}{\mu^3} = 0·1330$ to unity, or 13·3 per cent., as the probable error—a figure which is very high, and suggestive of the view that the number of cases is too few for us to accept the mortality rate of 33 per cent. as found, as being approximately correct.

The application of averages or means, when obtained, it will be seen, are of great importance, but only when founded on a sufficient number of cases. There is always a danger of attaching too much value to means or averages, forgetting how great a range there may be above and below them, and it is by reminding us constantly of this that calculations of the mean and probable errors, as well as the use of Poisson's rule, are so useful.

APPENDIX.

MEASURES OF LENGTH.

THE **Standard Metre** is $\frac{443296}{864000}$ of the distance, at the temperature of 16·3° C., between the ends of a certain bar, called the "Toise of Peru," kept in the French Archives, and is approximately the ten-millionth part of the distance from one of the earth's poles to the Equator, at the meridian of Paris. This measure, and those founded on it, is lawful in this country, and a copy of the standard metre is kept in the Exchequer Office at Westminster.

The English **Standard Yard** is the distance, at the temperature of 62° F., between two marks on a certain bar which is kept in the office of the Exchequer.

The relative values of the Metric and English measures of length can be gathered from the following table :—

	Metres.	Inches.	Feet.	Yards.	Miles.
Kilometre . .	1000	—	—	—	0·6214
Hectometre . .	100	—	—	—	—
Decametre . .	10	—	—	—	—
Metre . . .	**1**	**39·37**	**3·28**	**1·0936**	—
Decimetre . .	0·1	—	—	—	—
Centimetre . .	0·01	—	—	—	—
Millimetre . .	0·001	0·03937	—	—	—

MEASURES OF AREA.

	Square Metres.	British Measures of Area.	
Square Kilometre	1000000	0·3861	sq. miles.
,, Hectometre, or Hectare	10000	2·4711	acres.
,, Decametre, or Are . .	100	119·6	sq. yards.
,, **Metre**	**1**	**10·764**	sq. feet.
,, Decimetre . . .	0·01	15·5	sq. inches.
,, Centimetre	0·0001	0·155	,,
,, Millimetre	0·000001	0·00155	,,

SOLID MEASURES.

1 Cubic	Decametre, or Kilostere,	equals	35,316·5	cubic feet.
,,	**Metre, or Stere,**	,,	**35·3**	,,
,,	Decimetre, or Millistere,	,,	61·025	cubic inches.
,,	Centimetre	,,	0·061	,,
,,	Millimetre	,,	0·000061	,,

MEASURES OF WEIGHT.

The metric **Standard Kilogramme** is the weight, at the temperature of the maximum density of water (4° C.), and under the atmospheric pressure of 760 millimetres of mercury, in the latitude of Paris, of a certain piece of platinum which is kept in the French Archives. A copy of this standard kilogramme is kept in our Exchequer Office. The kilogramme was at first intended to be the weight of one cubic decimetre of pure water at its maximum density, but it is in actual fact slightly greater.

The English **Standard Pound Avoirdupois** is the weight, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury, in the latitude of London, and at or near the level of the sea, of a certain piece of platinum, which is kept in the Exchequer Office at Westminster.

The relative values of the Metric and English weights is shown in the following table:—

	Grammes.	Grains.	Avoir. ozs.	Avoir. lbs.
Kilogramme . . .	**1000**	**15432**	**35·3**	**2·2**
Hectogramme . .	100	—	—	—
Decagramme . . .	10	—	—	—
Gramme	1	15·432	0 0353	0·0022
Decigramme . . .	0·1	—	—	—
Centigramme . .	0·01	—	—	—
Milligramme . . .	0·001	0·0154	—	—

MEASURES OF CAPACITY.

The metric **Standard Litre** is the volume of a kilogramme of pure water at its temperature of maximum density (4° C.) and under the atmospheric pressure of 760 millimetres of mercury. It was originally intended to be a cubic decimetre, but is actually a little greater. Under the above-mentioned conditions, a litre of pure water weighs one kilogramme.

The English **Standard Gallon** is the volume of 10 lbs. avoirdupois of pure water, at the temperature of 62° F., and under the atmospheric pressure of 30 inches of mercury.

The relative values of the Metric and English measures of capacity is shown in the following table:—

	Cubic centimetres.	Fluid ozs.	Pints.	Gallons.	Cubic ins.
Kilolitre . .	1000000	—	—	—	—
Hectolitre . .	100000	—	—	—	—
Decalitre . .	10000	—	—	—	—
Litre . . .	**1000**	**35·3**	**1·76**	**0·22**	**61·027**
Decilitre . .	100	—	—	—	—
Centilitre . .	10	—	—	—	—
Millilitre . .	1	—	—	—	—

TABLE OF FACTORS FOR CALCULATING EQUIVALENTS OF WEIGHT, VOLUME, LENGTH, ETC.

To convert	grammes . .	to pounds,	multiply by	0·0022.
,,	,, . .	to grains,	,,	15·432.
,,	,, . .	to ounces,	,,	0·0353.
,,	grains . . .	to grammes,	,,	0·0648.
,,	ounces . . .	to ,,	,,	28·349.
,,	pounds . . .	to ,,	,,	453·592.
,,	kilogrammes .	to pounds,	,,	2·204.
,,	,, .	to ounces,	,,	35·3.
,,	litres . .	to gallons,	,,	0·22.
,,	,, . .	to fluid ounces,	,,	35·3.
,,	,, . . .	to pints,	,,	1·76.
,,	,, . .	to cubic feet,	,,	0·354.
,,	,, . . .	to cubic inches,	,,	61·027.
,,	gallons . .	to cubic feet,	,,	0·1605.
,,	,, . . .	to litres,	,,	4·5434.
,,	pints . . .	to ,,	,,	0·5679.
,,	,, . . .	to cubic centimetres,	,,	568·1818.
,,	,, . . .	to cubic inches,	,,	34·6592.
,,	cubic metres .	to gallons,	,,	0·0036.
,,	,, .	to pints,	,,	0·0288.
,,	,, .	to fluid ounces,	,,	0·5813.
,,	,, .	to cubic centimetres,	,,	16·4.
,,	cubic feet . .	to cubic metres,	,,	0·0283.
,,	,, . .	to litres,	,,	28·2153.
,,	,, . .	to gallons,	,,	6·2322.
,,	fluid ounces .	to cubic inches,	,,	1·72.
,,	,, .	to cubic centimetres,	,,	28·35.
,,	square feet . .	to square metres,	,,	0·0924.
,,	,, . .	to square yards,	,,	0·111.
,,	square metres .	to square feet,	,,	10·7641.
,,	inches . . .	to metres,	,,	0·0254.
,,	,, . . .	to millimetres,	,,	25·4.
,,	metres . . .	to inches,	,,	39·37.
,,	feet . .	to miles,	,,	0·000187.
,,	yards . . .	to miles,	,,	0·00057.
,,	,, . . .	to centimetres,	,,	2·54
,,	centimetres .	to inches,	,,	0·3937.
,,	millimetres .	to ,,	,,	0·03937.
,,	metres . . .	to feet,	,,	0·30479.
,,	kilometres . .	to miles,	,,	1·6.
,,	square kilometres	to square miles,	,,	2·5899.
,,	hectares . .	to acres,	,,	0·4046.

THE CHEMICAL SYMBOLS AND ATOMIC WEIGHTS OF ELEMENTARY BODIES.

Names of Elements.	Chemical Symbols.	Atomic Weights.	Names of Elements.	Chemical Symbols.	Atomic Weights.
Aluminium .	Al	27·5	Nitrogen .	N	14·0
Antimony .	Sb	120·0	Oxygen .	O	16 0
Arsenic . .	As	75·0	Palladium .	Pd	105·7
Barium . .	Ba	137·0	Phosphorus .	P	31·0
Bromine . .	Br	80·0	Platinum .	Pt	197·2
Cadmium	Cd	112·0	Potassium .	K	39·0
Calcium . .	Ca	40·0	Rubidium .	Rb	85·3
Carbon . .	C	12·0	Selenium .	Se	78·8
Chlorine . .	Cl	35·5	Silicon . .	Si	28·0
Chromium .	Cr	52·5	Silver . .	Ag	108·0
Cobalt . .	Co	59·0	Sodium . .	Na	23·0
Copper .	Cu	63·2	Strontium .	Sr	87·4
Fluorine . .	F	19·0	Sulphur . .	S	32·0
Gold . . .	Au	196·2	Tantalum .	Ta	182·0
Hydrogen .	H	1·0	Tellurium .	Te	125·0
Iodine . .	I	126 6	Thallium .	Tl	203·7
Iridium . .	Ir	192·7	Thorium .	Th	231·5
Iron . . .	Fe	56·0	Tin . . .	Sn	118·0
Lead . . .	Pb	206·5	Titanium .	Ti	48·0
Lithium . .	Li	7·0	Tungsten .	W	184·0
Magnesium .	Mg	24·0	Uranium .	U	240·0
Manganese .	Mn	55·0	Vanadium .	V	51·3
Mercury . .	Hg	200·0	Yttrium . .	Y	88·0
Molybdenum	Mo	95·5	Zinc . . .	Zn	65·0
Nickel . .	Ni	59·0	Zirconium .	Zr	89·4

INDEX.

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[illegible] Hydro[illegible] $C_{10}H_{18}O$

Starch $C_6H_{10}O_5$ under the influence of heat [illegible] [illegible] taking up of H_2O to form

$C_6H_{12}O_6$ = Grape Sugar

$C_{12}H_{22}O_{11}$ = cane "

Fat (meat) = C. O. H (mostly C).

[illegible] (meat) = C. O. H. N. S (a little).